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GIFT OF
Miss Sue Dunbar

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FIAT LVX
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EX LIBRIS

16 + 33½ Farmer
19 + 33
12½ + 12 + 10½
26 + 22½ + 23½
21 + + + - - -
34½ + 30½ - - -

Coat

Coat 16-35
19-32½
14-12-10
25½-22-23½
19½-
33
30

Vest 26+33.30.

Pants. 26½-42½
29.20½-14½-29.15

Fields

Otto Wandzetta

11½ + 22½

15½ + 24½

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X 19½ + 31½ + 24 Paul X

15 + 11 +

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X 16 + 25 + 25 Vast X

THE

PLANETARIUM,

AND

ASTRONOMICAL CALCULATOR,

Containing the Distances, Diameters, Periodical and Diurnal Revolutions of all the Planets in the Solar System, with the Diameters of their Satellites, their distances from, and the periods of their Revolutions around their respective Primaries; together with the method of calculating those Distances, Diameters and Revolutions. Also the method of calculating Solar and Lunar Eclipses; being a compilation from various celebrated authors, with Notes, Examples and Interrogations; prepared for the use of Schools and Academies.

BY

TOBIAS OSTRANDER,

TEACHER OF MATHEMATICS,

AND

AUTHOR OF THE ELEMENTS OF NUMBERS, EASY INSTRUCTOR,

MATHEMATICAL EXPOSITOR, &C.

> "Consult with reason, reason will reply,
> "Each lucid point, which glows in yonder sky,
> "Informs a system in the boundless space,
> "And fills with glory its appointed place;
> "With beams unborrow'd brightens other skies,
> "And worlds, to thee unknown, with heat and life supplies."

LYONS:

PRINTED AT THE OFFICE OF THE WESTERN ARGUS,

1832.

Northern District of New-York, TO WIT :—

BE it remembered, that on the sixteenth day of July, Anno Domini, 1832, TOBIAS OSTRANDER of the said district, hath deposited in this office the title of a book, the title of which is in the words following, to wit :

The Planetarium and Astronomical Calculator, containing the Distances, Diameters, Periodical and Diurnal Revolutions of all the Planets in the Solar system, with the Diameters of their Satellites, their distances from, and the periods of their Revolutions around their respective Primaries ; together with the method of calculating those Distances, Diameters and Revolutions ; and the method of calculating Solar and Lunar Eclipses ; being a compilation from various celebrated authors, with Notes, Examples and Interrogations ; prepared for the use of Schools and Academies. By TOAIAS OSTRANDER, Teacher of Mathematics, and author of the Elements of Numbers, Easy Instructor, Mathematical Expositor, &c.

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The right whereof he claims as Compiler and Proprietor, in conformity with an act of Congress, entitled an Act to amend the several Acts respecting Copy Rights.

RUTGER B. MILLER,
Clerk of the Northern District of New-York.

Gift of Miss Sue Dunbar

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1832

PREFACE.

In presenting the following pages to the public, I will briefly remark, that the people generally are grossly ignorant in the important and engaging science of Astronomy. Scarcely one in a county is found capable of calculating with exactness, and accuracy the precise time of an eclipse, or conjunction and opposition of the Sun and Moon. Is it for lack of abilities? No.—There are no people on the surface of this terraqueous globe, who possess better natural faculties of acquiring knowledge of any description, than those who inhabit the United States of America. In this land of liberty, much has been done, and much still remains to be done, for the benefit of the rising generation. Schools, Academies and Colleges have been erected, for the purpose of facilitating, and extending information and instruction among the youth of this delightful section. Gentlemen possessing the most profound abilities and acquirements, have engaged in the truly laudable employment of disseminating a knowledge of all the sciences; both of useful and ornamental description. Still this branch of the Mathematical science, called Astronomy, has been almost totally neglected, especially among the common people. From what source has this originated? I answer, from a scarcity of books, well calcu-

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lated to give the necessary instruction. Though there are many productions possessing merit, and are of importance to the rising generation, yet they are deficient in the tables necessary for the calculation, and protraction of eclipses. The works of Ferguson, Enfield and others, from which this is principally compiled, contain all that is necessary ; but the expense renders them beyond the means of many, who perhaps posses the best abilities in our land. Extensive volumes are not well calculated for the use of Schools ; for a Student is under the necessity of reading so much unessential, and uninteresting matter, that the essence is lost, in the multiplicity of words ; and for these reasons, many of the teachers have neglected this useful, and important branch of the Mathematical science. I have long impatiently beheld the evil, without an opportunity of providing a remedy, until the present period.

I now present to this enlightened community, a volume within the means of almost every person ; containing all the essential parts of Astronomy, adapted to the use of Schools and Academies ; made so plain and easy to be understood, that a lad of twelve years of age, whose knowledge of Arithmetic extends to the single rule of proportion, can, in the short space of one or two weeks, be taught to calculate an eclipse ; and many possessing riper years, from the precepts and examples given in the work, will be found capable of accomplishing it, without the aid of any other teacher.

The tables, (with the exception of two,) I have wholly calculated, and then duly compared them with those of Ferguson. Great care has also been taken, to present the work to the public, free from errors.

Should the following pages meet the approbation of a generous and enlightened community, and be the means of extending the knowledge of this important branch of Education; not only to the rising generation, but to those of maturer years, the Compiler, whose best abilities have hitherto been employed in endeavoring to meliorate the condition of man, by improving the mind and enlightening the understanding, will have the sublime satisfaction, of removing some of the shackles of ignorance, and building up a fund of useful and interesting knowledge upon its ruins.

THE COMPILER.

SECTION FIRST.

OF ASTRONOMY IN GENERAL.

Of all the sciences cultivated by mankind, Astronomy is acknowledged to be, and undoubtedly is, the most sublime, the most interesting, and the most useful. By the knowledge derived from this science, not only the magnitude of the earth is discovered, the situation and extent of the Countries and Kingdoms ascertained, trade and commerce carried on to the remotest parts of the world, and the various products of several countries distributed, for the health, comfort, and conveniency of its inhabitants; but our very faculties are enlarged, with the grandeur of the ideas it conveys, our minds exalted above the low contracted prejudices of the vulgar, and our understandings clearly convinced, and affected with the conviction, of the existence, wisdom, power, goodness, immutability, and superintendency of the Supreme Being. So that without any hyperbole, every man acquainted with this science, must exclaim with the immortal Dr. Young: "An undevout Astronomer is mad." From this branch of Mathematical knowledge, we also learn by what means, or laws, the Almighty Power and Wisdom of the Supreme Architect of the Uuiverse, are administered in continuing the wonderful harmony, order and connexion, observable throughout the planetary system; and are led by very powerful arguments, to form this pleasing and cheering sentiment, that minds capable of such deep researches, not only derive their origin from that Adorable Being, but are also incited to aspire after a more perfect knowledge of his nature, and a more strict conformity to his will.

By Astronomy we discover, that the earth is at so great a distance from the sun, that if seen from thence, it would appear no larger than a point; although its diameter is known to be nearly 8,000 miles: yet that distance is so small, compared with the earth's distance from the fixed stars, that if the orbit, in which the earth moves round the sun, were solid, and seen from the nearest star, it would likewise appear no larger than a point; although it is at least 190 millions of miles in diameter; for the earth in going round the sun, is 190 millions of miles nearer to some of the stars, at one time of the year than at another; and yet their apparent magnitudes, situations, and distances still remain the same; and a telescope which magnifies above 200 times, does not sensibly magnify them;

which proves them to be at least, one hundred thousand times further from us, than we are from the sun.

It is not to be imagined, that all the stars are placed in one concave surface, so as to be equally distant from us; but that they are placed at immense distances from one another, through unlimited space, so that there may be as great a distance between any two neighboring stars, as between the sun from which we receive our light, and those which are nearest to him. Therefore, an observer who is nearest any fixed star, will look upon it alone as a real sun; and consider the rest as so many shining points, placed at equal distances from him in the firmament,

By the help of telescopes, we discover thousands of stars which are entirely invisible, without the aid of such instruments, and the better our glasses are, the more become visible. We therefore can set no limits to their numbers, or to their immeasurable distances. The celebrated Huygens carried his thoughts so far, as to believe it not impossible, that there may be stars at such inconceivable distances, that their light has not yet reached the earth since their creation; although the velocity of light, be a million of times greater than the velocity of a cannon ball at its first discharge; and as Mr. Addison justly observes, " This thought is far from being extravagant, when we consider that the Universe is the work of Infinite Power, prompted by Infinite Goodness, and having an Infinite space to exert itself in; therefore our finite imaginations can set no bounds to it."

The Sun appears very bright and large, in comparison of the fixed stars; because we constantly keep near the Sun, in comparison to our immense distance from them. For a spectator placed as near to any star, as we are to the Sun, would see that star to be a body as large and bright as the Sun appears to us; and a spectator as far distant from the Sun, as we are from the stars, would see the Sun as small as we see a star, divested of all its circumvolving planets, and would reckon it one of the stars, in numbering them.

The stars being at such immense distances from the Sun, cannot possibly receive from him so strong a light as they appear to have, nor any brightness sufficient to make them ~~visible to us ; for the~~ Sun's rays must be so scattered before they reach such remote objects, that they can never be transmitted back to our eyes; so as to render these objects visible by reflection.—Therefore the stars, like the Sun, shine with ther own native and unborrowed lustre; and since each particular one, as well as the Sun, is confined to a particular portion of space, it is evident that the stars are of the same nature with the Sun; formed of similar materials, and are placed near the centres of as many magnificent systems; have a retinue of worlds inhabited by intelligent beings, revolving round them as their common centres; receive the distribution of their rays, and are illuminated by their beams; all of which, are lost to us, in immeasurable wilds of ether.

It is not probable that the Almighty, who always acts with Infinite Wisdom, and does nothing in vain, should create so many glorious Suns, fit for so many important purposes, and place them at such distances from each other without proper objects near enough to be benefitted by their influences. Whoever imagines that they were created only to give a faint glimmering light to the inhabitants of this globe, must have a very superficial knowledge of Astronomy, and a mean opinion of the Divine Wisdom; since by an infinitely less exertion of creating power, the Deity could have given our earth much more light by one single additional Moon.

Instead of our Sun, and our world only in the Universe, (as the unskillful in Astronomy may imagine;) that science discovers to us, such an inconceivable number of Suns, Systems and Worlds, dispersed through boundless space, that if our Sun, with all the planets, Moons and Comets, belonging to the whole Solar System, were at once annihilated, they would no more be missed by an eye that could take in the whole compass of Creation, than a grain of sand from the Sea shore; the space they possess, being comparatively so small, that their loss would scarcely make a sensible blank in the Universe. Although Herschel, the outermost of our planets, revolves about the Sun, in an orbit of three thousand, six hundred millions of miles in diameter, and some of our Comets, make excursions more than ten thousand millions of miles beyond his orbit, and yet at that amazing distance, they are incomparably nearer the Sun, than to any of the fixed stars, as is evident, from their keeping clear of the attractive power of all the stars, and returning periodically by virtue of the Sun's attraction.

From what we know of our own System, it may be reasonably concluded, that all the rest are with equal wisdom contrived, situated and provided with accommodations for the existence of intelligent inhabitants. Let us therefore take a survey of the System to which we belong, the only one accessible to us, and from thence we shall be better able to judge of the nature and end of other systems of the Universe. Altho' there are almost an infinite variety in the parts of Creation, which we have opportunities of examining ; yet there is a general analogy running through, and connecting all the parts into one scheme, one design of dissemminating comfort and happiness to the whole Creation.— To an attentive observer, it will appear highly probaable, that the planets of our System, together with their attendants called Satellites or Moons, are much of the same nature with our earth, and destined for similar purposes ; for they are all solid opaque globes, capable of supporting animals and vegetables ; some are larger, some less, and one nearly the size of our earth.— They all circulate round the Sun, as the earth does, in a shorter, or longer time, according to their respective distances from him, and have, where it would not be inconvenient,) regular returns of Summer and Winter, Spring and Autumn. They have warmer and colder climates, as the various productions of our earth require, and of such as afford a possibility of discovering it, we observe a regular motion round their axes, like that of our earth, causing an alternate return of day and night, which is necessary for labour, rest, and vegetation, and that all parts of their surfaces may be exposed to the rays of the Sun.

Such of the planets as are farthest from the Sun, and therefore enjoy least of his light, have that deficiency made up by several Moons, which constantly accompany and revolve about them, as our Moon revolves around the earth. The planet Saturn has over and above a broad ring, encompassing it, which no where touches his body; which like a broad zone in the Heavens, reflects the same light very copiously on that planet; remote planets have the Sun's light fainter by day, than we, they have an addition to it, morning and evening, by one or more of their Moons, and a greater quantity of light in the night time.

On the surface of the Moon, (because it is nearer to us than any other of the celestial bodies,) we discover a nearer resemblance of our earth, for by the assistance of telescopes we observe the Moon to be full of high mountains, large vallies, and deep cavities. These similarities leave us no room to doubt, but that all planets, Moons and Systems, are designed to be commodious habitations for creatures endowed with capacities of knowing, and adoring their beneficent Creator.

Since the fixed stars are prodigious spheres shining by their own native light like our Sun, at inconceivable distances from each other, as well as from us, it is reasonable to conclude that they are made for similar purposes, each to bestow light, heat and vegetation on a certain number of inhabited planets, kept by gravitation within the sphere of its activity.

When we therefore contemplate on those ample and amazing structures, erected in endless magnificence over all the ethereal plains, when we look upon them as so many repositories of light, or fruitful abodes of life, when we consider that in all probability there are orbs vastly more remote than those which appear to our unaided sight, orbs whose effulgence, though travelling ever since the Creation, has not yet arrived upon our coast—

What an august, what an amazing conception does this give of the works of the Omnipotent Creator; who made use of no preparatory measures, or long circuit of means. He spake, and ten thousand times ten thousand Suns, multiplied without end, hanging pendulous in the great vault of Heaven, at immense distances from each other, attended by ten thousand times ten thousand worlds, all in rapid motion, yet calm, regular, and harmonious, invariably keeping the paths prescribed, rolled from his creating hand.

But when we contemplate on the power, wisdom, goodness, and magnificence of the Great Creator; let us use the language of the immortal Dr. Young, in his appeal to the starry Heavens:—

————————"Say proud arch,
Built with Divine ambition, in disdain
Of limit built; built in the taste of Heaven,
Vast concave, ample dome. Wast thou designed
A meet apartment for the Deity?
Not so; that thought alone thy state impairs,
Thy lofty sinks, and shallows thy profound,
And straightens thy diffusive."

INTERROGATIONS FOR SECTION FIRST.

What is Astronomy ?

It is a mixed Mathematical Science, teaching the knowledge of the celestial bodies, their magnitudes, motions, distances, periods, eclipses and order.

What are its uses ?

What conviction does a knowledge of this branch of science give to the understanding ?

What cheering sentiment is formed from a knowledge of this science ?

What is the diameter of the earth ?

How many miles is the diameter of the earth's orbit ?

How is it known that the stars are at immense distances from us ?

How is it known that they are at immense distances from each other ?

What instruments have been invented to aid the sight of man ?

Who supposed there were stars, whose light had not yet reached the earth since their first creation ?

Who confirmed the idea ?

Why cannot the same rays be reflected back from the stars to our eyes ?

With what light do the stars shine ?

How could the Deity have given us greater light in the night time, than by the whole starry host ?

How is it known that the Comets belong to the Solar System ?

From what parity of reasoning, is it believed that the stars are so many suns, and have worlds revolving about them ?

How are those planets supplied with light, which are farthest from the Sun ?

SECTION SECOND.

OF THE SOLAR SYSTEM.

The Solar System consists of the Sun, with all the Planets and Comets that move around him as their centre. Those which are near the Sun, not only finish their circuits sooner, but likewise move with greater rapidity in their respective orbits, than those which are more remote. Their motions are all performed from West to East, in Elliptical orbits. Their names, distances, magnitudes, and periodical revolutions, are as follows :—The Sun is placed near the common centre, or rather in the lower focus of the orbits of all the planets and comets, and turns round on his axis once in 25 days, 14 hours and 8 minutes; as has been proved, from the motion of the spots, seen on his surface. His diameter is computed at 883,246 miles, and by the various attractions of the convolving planets, he is agitated by a small motion round the centre of gravity of the system. His mean apparent diameter as seen from the earth, is 32 minutes and one second. His solidity, and indeed that of every other planet, may be found by multiplying the cube of their diameters by ,5236. All the planets as seen by a spectator, placed on the sun, move the same way, and according to the order of the signs, Aries, Taurus, Gemini, &c. which represent the great ecliptic. But, to a spectator placed on any one of the planets, the others sometimes appear to go backward, sometimes forward, and at others stationary ; not moving in proper circles, nor elliptical orbits, but in looped curves, which never return into themselves.

The Comets, also appear to come from all parts, and appear to move in various directions. These proofs are sufficient to establish the fact, that the sun is placed near the centre, and that all the other planets revolve around him : are irradiated by his beams : receive the distribution of his rays, and are dependant for the enjoyment of every blessing on this grand dispensor of divine munificence.

The orbits of the planets are not in the same plane with the ecliptic,* but crosses it in two points directly opposite to each other, called the planet's nodes.†—That from which the planet ascends northward above the ecliptic, is called the ascending node ; and the other which is directly opposite, (and consequently 6 signs asunder,) is called the descending node.

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* The ecliptic is an imaginary great circle in the Heavens, in the plane of which the earth performs her annual revolutions round the sun.

† The node is the intersection of the orbit of any planet with that of the earth.

It was discovered on the first of January 1805, that the ascending node of the planet Herschel was in twelve degrees and fifty-three minutes of the sign Gemini, and advances 16 seconds in a year. Saturn in twenty-one degrees and 59 minutes of Cancer, and advances 32 seconds in a year. Jupiter in 8 degrees and 27 minutes of Cancer, and advances 36 seconds yearly. Mars in 18 degrees, and four minutes of Taurus, and advances 28 seconds yearly. Venus in 14 degrees and 55 minutes of Gemini, and advances 36 seconds yearly. Mercury in 16 degrees of Taurus, and advances 43 seconds every year. In these observations, the earth's orbit is considered the standard, and the orbits of all the other planets obliquely to it. The nearest planet to the sun is Mercury. The great brilliancy of light emitted by this planet: the shortness of the period during which observations can be made upon his disk; and his position among the vapors of the horizon when he is observed, have hitherto prevented Astronomers, from making interesting discoveries to be relied on with certainty respecting this planet. This planet, when viewed at different times with a good telescope, appears in all the various shapes of the Moon, which is a plain proof that he receives, (like the Moon,) all his light from the Sun. That he moves round the Sun in an orbit, within the orbit of the earth, is also plain; because he is never seen opposite to the Sun, nor above 56 times the Sun's diameter from his centre. It has been said by Authors, that his light and heat from the Sun must be almost seven times as great as our's;

judging from his nearness to it. His light and heat however, depend more on the height and density of his atmosphere, than to his near approach to that luminary.

His distance from the Sun is computed at 73,000,000 of miles, is 3,225 in diameter, and performs a revolution round the Sun, in 87 days 23 hours 15 minutes and 28 seconds: his apparent diameter as seen from the earth, is ten seconds. His orbit is inclined,7 degrees to the ecliptic; and that node from which he ascends northward above it, is in the 16th degree of Taurus, the opposite in the 16th degree of Scorpio. The earth is in these points on the 6th of November, and 4th of May; when he comes to either of his nodes at his inferior conjunction about these times, he will appear to pass over the face of the sun like a dark round spot.—But in all other parts of his orbit, his conjunctions are invisible; because he either goes above or below the Sun. On the 5th day of May, at 6 hours 43 minutes 22 seconds in the morning, in the year 1832, in the longitude of Washington, he was in conjunction with the Sun. His next visible conjunction will be on the 7th day of November 1835.

Venus, the next planet in order is 68,000,000 of miles from the Sun by computation, and by moving at the rate of 69,000 miles every hour in her orbit, she performs her revolution round the Sun in 224 days, 16 hours and 49 minutes of our time; in which, (though it be the full length of her year,) she has only 9 days and a quarter, according to observations made by Bianchini; so that her every day and night together, is as long as 348⅓ days and nights with us. This odd quarter of a day in every year, makes in every fourth year a leap year to Venus, as the like does to the earth which we inhabit. Her diameter is computed at 7687 miles, and performs her diurnal revolutions in 23 hours 20 minutes, and 54 seconds; with an inclination of her orbit to the ecliptic, of 3 degrees 23 minutes, and 35 seconds. Her orbit includes the orbit of Mercury within it, for at her greatest elongation, or apparent distance from the Sun, she is about 96 times his diameter from his centre; while that of Mercury is not above 56.

Her orbit is included within the orbit of the earth, for if it were not, she would be as often seen in opposition as in conjunction with the Sun. But she never departs from the Sun to exceed 47 degrees, and that of Mercury 28, it is therefore certain that the orbit of Mercury is within the orbit of Venus, and that of Venus within the orbit of the earth. When this planet is west of the Sun, she rises in the morning before him, and hence she is called the morning star; and when she sets after the Sun, she is called the evening star; so that in one part of her orbit she rides foremost in the procession of night, and in the other, anticipates the dawn; being each in its turn 290 days. The axis of Venus is inclined 75 degrees to the axis of her orbit, which is 51 degrees and 32 minutes more than the axis of the earth is inclined to the axis of the ecliptic; and therefore her seasons vary much more than our's.

The north pole of her axis, inclines towards the 20th degree of Aquarius; the earth's to the beginning of Cancer. Consequently the northern parts of Venus have Summer, in the signs where those of the earth have Winter, and vice versa. The orbit of Venus is inclined three and one half degrees to the earth's, and crosses it in the 14th degree of Gemini, and Sagittarius, and therefore when the earth is near the points of the ecliptic, at the time when Venus is in her inferior conjunction,* she appears like a spot on the Sun, and it furnishes a true method of calculating the distances of all the planets from the Sun.

It will not be uninteresting to those who peruse this treatise, to be put in the possession of all the elements of the transits, both of Mercury and Venus over the Sun's disk; from this period to the end of the present century, I therefore insert the following tables :—

TRANSIT OF MERCURY OVER THE SUN'S DISK.

Transit of Mercury May 4th 1832.

	D	H.	M.	S.
Mean time of conjunction, May - -	4	23	51	22
	S	D.	M.	S.
Geocentric longitude of the Sun and Mercury -	1	14	56	45
		H	M.	S.
Middle apparent time, - - -		0	18	1
Semi-duration of the transit, - -		3	28	2
Nearest approach to centres, - - -			8	16 North.

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* Inferior conjunction is, when the planet is between the earth and the Sun, in the nearest part of its orbit.

November 7th 1835.

		H.	M.	S.	
Mean time of conjunction,		7	47	54	
	S.	D.	M.	S.	
Geocentric longitude of the Sun and Mercury,	7	14	43	8	
		H.	M.	S.	
Middle apparent time,		8	12	22	
Semi duration of the transit,		2	33	53	
Nearest approach of centres,		0	5	37	South.

May 8th 1845.

		H.	M.	S.	
Mean time of Conjunction.		7	54	18	
	S.	D.	M.	S.	
Geocentric longitude of the Sun and Mercury,	1	18	1	49	
		H.	M.	S.	
Middle apparent time,		7	32	58	
Semi-duration of the transit,		3	22	33	
Nearest approach of centres,		0	8	58	South.

November 9th 1848.

		H.	M.	S.	
Mean time of conjunction,		1	37	43	
	S.	D.	M.	S.	
Geocentric longitude of the Sun and Mercury,	7	17	19	19	
		H.	M.	S.	
Middle apparent time,		1	49	43	
Semi-duration of the transit,		2	41	33	
Nearest approach of centres,			2	36	North.

November 11th 1861.

		H.	M.	S.	
Mean time of conjunction,		19	20	13	
	S.	D.	M.	S.	
Geocentric longitude of the Sun and Mercury	7	19	54	44	
		H.	M.	S.	
Middle apparent time,		19	20	14	
Semi-duration of the transit,		2	0	23	
Nearest approach of centres,		0	10	52	North.

November 4th 1868.

	H.	M.	S.
Mean time of conjunction,	18	43	45
Middle apparent time,	19	18	24
Semi-duration of the transit,	1	45	21

	S.	D.	M.	S.
Geocentric longitude of the Sun and Mercury,	7	13	9	42
Nearest approach of centres,			12	20 South.

May 6th 1878.

	H.	M.	S.
Mean time of conjunction,	6	38	30
Middle apparent time,	6	55	14
Semi-duration of the transit,	3	53	31

	S.	D.	M.	S.
Geocentric longitude of the Sun and Mercury,	1	16	3	50
Nearest approach of centres,			4	39 North.

November 7th 1881.

	H.	M.	S.
Mean time of conjunction,	12	39	38
Middle apparent time,	12	59	33
Semi-duration of the transit,	2	39	6

	S.	D.	M.	S.
Geocentric longitude of the Sun and Mercury,	7	15	46	57
Nearest approach of centres,			3	57 South.

May 9th 1891.

	H.	M.	S.
Mean time of conjunction,	14	44	57
Middle apparent time,	14	13	46
Semi-duration of the transit,	2	34	20

	S.	D.	M.	S.
Geocentric longitude of the Sun and Mercury,	1	19	9	1
Nearest approach of centres,		0	12	21 South.

November 10th 1894.

	H.	M.	S.
Mean time of conjunction,	6	17	5
Middle apparent time,	6	36	29
Semi-duration of the transit,	2	37	36

	S.	D.	M.	S.
Geocentric longitude of the Sun and Mercury,	7	18	22	9
Nearest approach of centres,			4	20 North.

TRANSITS OF VENUS OVER THE SUN'S DISK, FROM THE YEAR 1769 TO THE YEAR 2004 INCLUSIVE.

June 3*d* 1769.

	H	M.	S.
Mean time of conjunction, - -	9	58	34
Middle apparent time, - - -	10	27	3
Duration of the transit, - -	5	59	46

	S	D.	M.	S.	
Geocentric longitude of the Sun and Venus,	2	13	27	8	
Nearest approach of centres, - -		0	10	10	North.

December 8*th* 1874.

	H	M.	S.
Mean time of conjunction, - -	16	8	24
Middle apparent time, - - -	15	43	28
Duration of the transit, - -	4	9	22

	S	D.	M.	S.	
Geocentric longitude of the Sun and Venus,	8	16	57	49	
Nearest approach of centres, - -		0	13	51	North.

December 6*th* 1882.

	H	M.	S.
Mean time of conjunction, - -	4	16	24
Middle apparent time, - -	4	49	42
Duration of the transit, - - -	6	3	26

	S	D.	M.	S.	
Geoncentric longitude of the Sun and Venus,	8	14	29	14	
Nearest approach of centres, - -			10	29	South.

June 7*th* 2004.

	H	M.	S.
Mean time of conjunction, - - -	20	51	24
Middle apparent time, - - -	20	26	59
Duration of the transit, - - -	5	29	40

	S	D.	M.	S.	
Geocentric longitude of the Sun and Venus,	2	17	54	23	
Nearest approach of centres, - -			11	19	South.

The earth is the next planet above Venus, in the Solar Sytem ; it is 95,000,000 of miles from the Sun, and performs a revolution around him, from any Solstice, or Equinox, to the same again, in 365 days, 5 hours and 49 minutes: but from any fixed star to the same again, in 365 days, 6 hours and 9 minutes. The former being the length of the tropical year, and the latter the sidereal. It travels at the rate of 58,000 miles every hour, in performing its annual revolution. It revolves on its own axis from West to East, once in 24 hours. Its mean diameter as seen from the Sun, is 17 seconds and two tenths of a degree. Which, by calculation, will give about 7,970 miles for its diameter. The form of the earth is an oblate spheroid, whose equatorial axis exceeds its polar by 36 miles, and is surrounded by an atmosphere extending 45 miles above its surface.

The Seas, and unknown parts of the earth, (by a measurement of the best Maps,) contain 160 millions, 522 thousand, and 26 square miles. The inhabited parts 38 millions, 990 thousand, 569. Europe four millions, 456 thousand, and 65. Asia 10 millions, 568 thousand, 823. Africa 9 millions, 654 thousand, 807. America 14 millions, 110 thousand, 874: the whole amounting to 199 millions, 512 thousand, 595; which is the number of square miles, on the whole surface of the Globe we inhabit.

The Moon is not a planet, but only a satellite, or an attendant of the earth, performing a revolution round it in 29 days, 12 hours and 44 minutes; and with the earth, is carried round the Sun once in every year.

The diameter of the Moon is 2,180 miles, and her mean distance from the earth's centre, is estimated at 240,000 miles. She goes around her orbit in 27 days, 7 hours and 43 minutes; moving about 2,290 miles every hour, and performs a revolution on her own axis exactly in the time that she goes round the earth; consequently the same side of her is continually presented towards the earth, and the length of her day and night taken together, is equal to a lunar month. Her mean apparent diameter, as seen from the earth, is 31 minutes and 8 seconds of a degree. The orbit of the Moon, crosses the ecliptic in two opposite points, called the Moon's nodes, consequently one half of her orbit is above the ecliptic, and the other below; the angle of its obliquity is 5 degrees, and 20 minutes.

The Moon has scarcely any difference of seasons, because her axis is nearly perpendicular to the ecliptic, and consequently the Sun never removes sensibly from her equator.

The earth which we inhabit, serves as a satellite to the Moon, waxing and waning regularly, but appearing thirteen times as large, and affording her, thirteen times as much light as the Moon does to us. When she is new to us, the earth appears full to her; and, when she is in her first quarter as seen from the earth, the earth is in its third quarter as seen from the Moon.

The Moon is an opaque globe, like the earth, and shines only by reflecting the light of the Sun; therefore whilst that half of her which is towards the Sun, is enlightened, the other half must be dark and invisible. Hence she disappears when she comes between us and the Sun; because her dark side is then towards us.

The planet Mars is next in order, being the first above the earth's orbit. His distance from the Sun is computed at 144,000,000 of miles, and by travelling at the rate of 54,000 miles every hour, he goes round the Sun in 686 of our days, 23 hours and 30 minutes, which is the length of his year, equal to 667 and 3-4th of his days; and every day and night together, being nearly 40 minutes longer than with us. His diameter is computed at 4,189 miles, and by his diurnal rotation, the inhabitants at his equator are carried 528 miles every hour. The Sun appears to the inhabitants of Mars, nearly two-thirds the size that it does to us.

His mean apparent diameter, as seen from the earth is 27 seconds, and as seen from the Sun, ten seconds of a degree. His axis is inclined to his orbit 59 degrees and 22 minutes.

To the inhabitants of the planet Mars, our Earth and Moon appear like two Moons; the one being 13 times as large as the other; changing places with each other, and appearing sometimes horned, sometimes half or three-quarters illuminated but never full, nor at most above one quarter of a degree from each other; although they are in fact 240,000 miles asunder.

This Earth appears almost as large from Mars as Venus does to us. It is never seen above 48 degrees from the Sun, at that planet. Sometimes it appears to pass the disk of the Sun, and likewise Mercury and Venus. But Mercury can never be seen from Mars by such eyes as our's (unless assisted by proper instruments,) and Venus will be as seldom seen as we see Mercury. Jupiter and Saturn are as visible to Mars as to us. His axis is perpendicular to the ecliptic, and his inclination to it is one degree and 51 minutes. The planet Mars is remarkable for the redness of its light, the brightness of its polar regions, and the variety of spots which appear upon its surface. The atmosphere of this planet, which Astronomers have long considered to be of an extraordinary height and density, is the cause of the remarkable redness of its appearance. When a beam of white light passes through any medium, its color inclines to redness, in proportion to the density of the medium; and the space through which it has travelled. The momentum of the red, or least refrangible rays being greater than that of the violet, or most refrangible, the former will make their way through the resisting medium, while the latter are either reflected or absorbed. The color of the beam therefore when it reaches the eye, must partake of the color of the least refrangible rays, and must consequently increase with the number of those of the violet, which have been obstructed.—Hence we discover, that the morning and evening clouds are beautifully tinged with red, that the Sun, Moon and Stars appear of the same color, when near the horizon, and that every luminous object seen through a mist, is of a ruddy hue. There is a great difference of color among the planets, we are therefore, (if the preceding observations be correct,) under the necessity of concluding, that those in which the red color predominates, are surrounded with the most extensive and dense atmospheres. According to this idea, the atmosphere of Saturn, must be the next to that of Mars, in density and extent.

The planet Mars is an oblate spheroid, whose equatorial diameter is to the polar as 1,355 is to 1,272, or nearly as 16 to 15. This remarkable flattening at the poles of Mars, probably arises from the great variation in the density of his different parts.

VESTA.

Some Astronomers supposed that a planet existed between the orbits of Jupiter and Mars; judging from the regularity observed in the distances of the former discovered planets from the Sun. The discovery of Ceres confirmed this conjecture, but the opinion which it seemed to establish respecting the harmony of the Solar System, appeared to be completely overturned, by the discovery of Pallas and Juno. Dr. Olders, however imagined that these small celestial bodies were merely the fragments of a larger planet which had burst asunder by some internal convulsion, and that several more might yet be discovered between the orbits of Mars and Jupiter. He therefore concluded that though the orbits of all these fragments might be inclined to the ecliptic, yet as they must have all diverged from the same point, they ought to have two common points of reunion, or two nodes in opposite regions of the Heavens, through which all the planetary fragments must sooner or later pass. One of these nodes he found to be in Virgo, and the other in the Whale, and it was actually in the latter of these regions, that Mr. Harding discovered the planet Juno. With the intention therefore of detecting other fragments of the supposed planet, Dr. Olders examined thrice every year all the little stars in the opposite constellations of the Virgin, and the Whale, till his labors were crowned with success on the 29th of March, 1807, by the discovery of a new planet in the constellation Virgo, to which he gave the appropriate name of Vesta. The planet Vesta is the next above Mars, and is in appearance of the fifth or sixth magnitude, and may be seen in a clear morning by the naked eye. Its light is more intense, pure and white, than either of the three following Ceres, Juno, or Pallas. Its distance from the Sun is computed at 225 millions of miles, and its diameter at 238 : its revolutions have not hitherto been sufficiently ascertained.

ON JUNO.

The planet Juno, the next above Vesta, and between the orbits of Mars, & Jupiter was discovered by Dr. Harding, at the Observatory near Bremen, on the evening of the 5th of September, 1804. This planet is of a reddish color, and is free from that nebulosity which surrounds Pallas. It is distinguished from all the other planets by the great excentricity of its orbit, and the effect of this is so extremely sensible, that it passes over that half of its orbit which is bisected by its perihelion in half the time that it employs in describing the other half, which is further from the Sun; from the same cause its greatest distance from the Sun is double the least. The difference between the two being about 127 millions of miles. Its mean distance from the Sun is computed at 252 millions of miles, and performs its tropical revolution in 4 years and 128 days. Its diameter is estimated at 1,425 miles, and its apparent diameter as seen from the Earth, three seconds of a degree, and its inclination of orbit twenty-one degrees.

ON CERES.

The planet Ceres was discovered at Palermo, in Sicily, on the first of January, 1801, by M. Riazzi, an ingenious observer, who has since distinguished himself by his Astronomical labors. It was however again discovered by Dr. Olders, on the first of January, 1807, nearly in the same place where it was expected from the calculations of Baron Zach. The planet Ceres is of a ruddy color, and appears about the size of a star of the 8th magnitude. It seems to be surrounded with a large dense atmosphere of 675 miles high, according to the calculations of Schroeter, and plainly exhibits a disk, when examined, with a magnifying power of 200.

Ceres is situated between the orbits of Mars and Jupiter. She performs her revolution round the Sun in four years, 7 months and ten days; and her mean distance is estimated at 263 millions of miles from that luminary. The observations which have been hitherto made upon this celestial body, do not appear sufficiently correct to determine its magnitude with any degree of accuracy.

ON PALLAS.

The planet Pallas was discovered at Bremen, in Lower Saxony, on the evening of the 28th of March, 1802, by Doctor Olders, the same active Astronomer, who re-discovered Ceres. It is situated between the orbits of Mars and Jupiter, and is nearly of the same magnitude and distance with Ceres, but of a less ruddy color. It is seen surrounded with a nebulosity of almost the same extent, and performs its annual revolution in nearly the same period. The planet Pallas however is distinguished in a very remarkable manner from Ceres, and all the primary planets, by the immense inclination of its orbit. While these bodies are revolving round the Sun in almost circular paths, rising only a few degrees above the plane of the ecliptic ; Pallas ascends above this plane, at an angle of about 35 degrees, which is nearly five times greater than the inclination of Mercury. From the eccentricity of Pallas being greater than that of Ceres, or from a difference of position in the line of their apsides, where their mean distances are nearly equal, the orbits of these two planets mutually intersect each other ; a phenomenon which is altogether anomalous in the Solar System.

Pallas performs its tropical revolution in four years 7 months and 11 days. The distance of this planet, from the Sun, is estimated at 265 millions of miles. It is surrounded with an atmosphere 468 miles high.

OF JUPITER.

Jupiter, the largest of all the planets, is still higher in the Solar System, being four hundred and ninety millions of miles from the Sun, and by performing his annual revolution round the Sun in eleven years, 314 days, 20 hours and 27 minutes, he moves in his orbit at the rate of 29,000 miles in an hour. The diameter of this planet is estimated at 89,170 miles, and performs a revolution on its own axis in nine hours, 55 minutes and 37 seconds; which is more than 28,000 miles every hour, at his equator, the velocity of motion on his axis being nearly equal to the velocity with which he moves in his annual orbit.

This planet is surrounded by faint substances called belts, in which so many changes appear, that they have been regarded by some, as clouds or openings in the atmosphere of the planet; while others imagine that they are of a more permanent nature, and are the marks of great physical revolutions which are perpetually changing the surface of the planet.

The axis of Jupiter is so nearly perpendicular to his orbit, that he has no sensible change of seasons, which is a great advantage, and wisely ordered by the Author of nature; for if the axis of this planet were inclined any considerable number of degrees, just so many degrees round each pole would in their turn, be almost six of our years together in darkness, and, as each degree of a great circle on Jupiter contains 778 of our miles at a mean rate; judge ye what vast tracts of lands would be rendered uninhabitable by any considerable inclination of his axis.

The difference between the equatorial and polar diameters of this oblate spheroid is computed at 6,230 miles; for his equatorial diameter is to his polar, as13 is to 12; consequently his poles are 3,115 miles nearer his centre than his equator. This results from his rapid motion round his axis, for the fluids together with the light particles which they can carry, or wash away with them, recede from the poles, which are at rest towards the equator, where the motion is more rapid, until there be a sufficient number of such particles accumulated to make up the deficiency of gravity occasioned by the centrifugal force, which arises from a quick motion round an axis; and when the deficiency of weight or gravity of the particles is made up by a sufficient accumulation, the equilibrium is restored, and the equatorial parts rise no higher. The orbit of Jupiter is inclined to the ecliptic one degree and 20 minutes. His north node is in the 7th degree of Cancer, and his south node in the 7th degree of Capricorn. His mean apparent diameter as seen from the earth is 39 seconds, and as seen from the Sun, 37 seconds of a degree.

This planet being situated at so great a distance from the Sun, does not enjoy that degree of light emanating from his rays, which is enjoyed by the earth. To supply this deficiency, the great Author of our existence has provided 4 satellites, or Moons to be his constant attendants, which revolve around him, in such manner, that scarcely any part of this large planet but is enlightened during the whole night, by one or more of these Moons, except at his poles, where only the farthest Moons can be seen; there, however this light is not wanted; because the Sun constantly circulates in or near the horizon, and is very probably kept in view of both poles by the refraction of his atmosphere. The first Moon, or that nearest to Jupiter performs a revolution around him in one day, 18 hours and 36 minutes of our time, and is 229 thousand miles distant from his centre: the second performs his revolution in 3 days 13 hours and 15 minutes at a distance of 364 thousand miles: the third in seven days, three hours and 59 minutes, at the distance of 580 thousand miles, and the fourth, or farthest from his centre in 16 days, 18 hours, and 30 minutes, at the distance of one million of miles from his centre. The angles under which these satellites are seen from the earth, at its mean distance from Jupiter, are as follows:— The first three minutes and 55 seconds: the second six minutes and 15 seconds: the third 9 minutes and 58 seconds, and the fourth 17 minutes and 30 seconds. This planet when seen from its nearest Moon, must appear more than one thousand times as large as our Moon does to us.

The three nearest Moons to Jupiter, pass through his shadow, and are eclipsed by him, in every revolution, but the orbit of the fourth is so much inclined, that it passes by its opposition to Jupiter without entering his shadow, two years in every six. By these eclipses, Astronomers have not only discovered that the Sun's light is about 8 minutes in coming to us; but they have also determined the longitude of places on this earth with greater certainty, and facility than by any other method yet known.

OF SATURN.

Saturn is the most remarkable of all the planets, it is calculated at 9 hundred millions of miles from the Sun, and travelling at the rate of 21,900 miles every hour, and performs its annual circuit in 29 years, 167 days and 2 hours of our time; which makes only one year to that planet. Its diameter is computed at 79,042 miles, and performs a revolution on its own axis once in ten hours, 16 minutes and two seconds. Its mean apparent diameter as seen from the earth, is 18 seconds, and as seen from the Sun, 16 seconds of a degree; its axis is supposed to be 60 degrees inclined to its orbit.

This planet is surrounded by a thin broad ring, which no where touches its body, and when viewed by the aid of a good telescope appears double. It is inclined 30 degrees to the ecliptic, and is about 21 thousand miles in breadth; which is equal to its distance from Saturn on all sides. This ring performs a revolution on its axis in the same space of time with the planet, namely, ten hours 16 miutes and two seconds.—— This ring seen from the planet Saturn, appears like a vast luminous circle in the Heavens, and, as if it does not belong to the planet. When we see the ring most open, its shadow upon the planet is broadest, and from that time the shadow grows narrower, as the ring appears to do to us, until by Saturn's annual motion, the Sun comes to the plane of the ring, or even with its edge; which being then directed towards the earth, it becomes to us invisible on account of its thinness.—— The ring nearly disappears twice in every annual revolution of Saturn, when he is in the 19th degree, both of Pisces and Virgo. But, when Saturn is in the 19th degree either of Gemini or Sagitarius, his ring appears most open to us, and then its longest diameter is to its shortest as 9 to 4.

This planet is surrounded with no less than seven satellites, which supply him with light during the absence of the Sun. The fourth of these was first discovered by Huygens, on the 25th of March, 1655.—— Cassini discovered the fifth in October, 1671. The third on the 23d of december, 1672: And the first and second in the month of March, 1684. The sixth and seventh were discovered by Dr. Herschel in the year 1789. These are nearer to Saturn than any of the others.

These Moons perform their revolutions round this planet on the outside of his ring, and nearly in the same plane with it. The first, or nearest Moon to Saturn, performs its periodical revolution around him in 22 hours and 37 minutes, at the distance of 121,000 miles from his centre; the second performs its periodical revolution in one day, 8 hours and 53 minutes, at the distance of 156 thousand miles; the third in one day, 21 hours, 18 minutes and 26 seconds, at the distance of 193 thousand; the fourth in two days, 17 hours 44 minutes and 51 seconds, at the distance of 247 thousand; the fifth in 4 days, 12 hours, 25 minutes and 11 seconds, at 346 thousand; the 6th in15 days, 22 hours, 41 minutes and 13 seconds, at the distance of 802 thousand; and the 7th or outermost in 49 days, 7 hours, 53 minutes and 43 seconds, at the distance of two millions, 337 thousand miles from the centre of Saturn—their primary.

When we look with a good telescope, at the body of Saturn, he appears like most of the other planets, in the form of an oblate spheroid, arising from the rapid rotation about his axis. He however appears more flattened at the poles, than any of the others, and although his motion on his axis is not equal to that of Jupiter, yet he does not appear to be in form, so near that of a globe as that planet. When we consider that the ring by which Saturn is encompassed, lies in the same plane of his equator, and, that it is at least equal if not more dense than the planet, we shall find no difficulty in accounting for the great accumulation of matter, at the the equator of Saturn. The ring acts more powerfully upon the equatorial regions of Saturn; than upon any part of his disk; and by diminishing the gravity of these parts, it aids the centrifugal force in flattening the poles of the planet. Had Saturn indeed never revolved upon his axis, the action of the ring would of itself have been sufficient, to have given it the form of a spheroid.

The following, are the dimensions of this luminous zone, as determined by Dr. Herschel.

Inside diameter of the interior ring, -	146,345
Outside diameter of the interior ring, -	184,383
Inside diameter of the exterior ring, -	190,240
Outside diameter of the exterior ring, -	204,833
Breadth of the interior ring, - - -	20,000
Breadth of the exterior ring, - - -	7,200
Breadth of the dark space between the two rings,	2,839
Angle which it subtends when seen at the mean distance of the planet. - - - -	M. S. 7 25

ON HERSCHEL, OR URANUS.

From inequalities in the motion of Jupiter and Saturn, for which no rational account could be given, and from the mutual action of these planets, it was inferred by some Astronomers, that another planet existed beyond the orbits of Jupiter and Saturn; by whose action these irregularities were produced. This conjecture was confirmed on the 13th of March, 1781; when Dr. Herschel discovered a new planet, which in compliment to his Royal Patron, he called Georgium Sidus, although it is more generally known by the name of Herschel, or Uranus. This new planet, (which had been formerly observed as a small star by Flamstead, and likewise by Tobias Mayer, and introduced into their catalogue of fixed stars,) is situated, one thousand, eight hundred millions of miles from the centre of the System, and performs its revolution round the Sun in 83 years, 150 days, and 18 hours. Its diameter is computed at 35,112 miles. When seen from the earth, its mean apparent diameter is three and ⅓ seconds, and as seen from the Sun, 4 seconds of a degree. As the distance of this planet from the Sun is twice as great as that of Saturn, it can scarcely be distinguished without the aid of instruments. When the sky however is serene, it appears like a fixed star of the sixth magnitude, with a bluish white light, and a brilliancy between that of Venus and the Moon; but seen with a power of two or three hundred, its disk is visible and well defined.--The want of light arising from the distance of this planet from the Sun, is supplied by six satellites, all of which were discovered by Dr. Herschel.

The first of those satellites is twenty five and half seconds from its primary, and revolves round it in 5 days, 21 hours and 25 minutes; the second is nearly 34 seconds distant from the planet, and performs its revolution in 8 days, 17 hours, 1 minute and 19 seconds. The distance of the third satellite is 38,57 seconds, and the time of its periodical revolution is ten days, 23 hours, and four minutes. The distance of the fourth satellite is 44,22 seconds, and the time of its periodical revolution is 13 days, 11 hours, 5 minutes and 30 seconds. The distance of the fifth is one minute and 28 seconds, and its revolution is completed in 38 days, 1 hour, and 49 minutes. The sixth satellite, or the furthest from the centre of its primary, at the distance of two minutes, and nearly 57 seconds, and therefore requires 107 days, 16 hours, and 40 minutes to complete one revolution. The second and fourth of these were discovered on the 11th of January, 1787, the other four were discovered in 1790, and 1794; but their distantances, and times of periodical revolution, have not been so accurately ascertained as the other two. It is however, a remarkable circumstance, that the whole of these satellites move in a retrogade direction, and in orbits lying in the same plane, and almost perpendicular to the ecliptic.

When the Earth is in its perihelion, and Herschel in its aphelion, the latter becomes stationary, as seen from the Earth, when his elongation, or distance from the Sun is 8 signs, 17 degrees, and 37 minutes, his retrogradations continue 151 days, and 12 hours. When the Earth is in its aphelion, and Herschel in its perihelion, it becomes stationary, at an elongation of 8 signs, 16 degrees, and 27 minutes, and its retrogadations continue 149 days and 18 hours.

ON COMETS.

Comets are a class of celestial bodies, which occasionly appear in the Heavens. They exhibit no visible or defined disk, but shine with a pale and cloudy light, accompanied with a tail or train, turned from the Sun. They traverse every part of the Heavens, and move in every possible direction.

When examined through a good telescope, a Comet resembles a mass of aquious vapors, encircling an opaque nucleus, of different degrees of darknes in different Comets ; though sometimes, as in the case of several discovered by Dr. Herschel, no nucleus can be seen.

As the Comet advances towards the Sun, its faint and nebulous light becomes more brilliant, and its luminous train gradually increases in length.

When it reaches its perihelion, the intensity of its light, and the length of its tail reaches their maximum, and then it sometimes shines with all the splendor of Venus. During its retreat from the perihelion, it is shorn of its splendor, and it gradually resumes its nebulous appearance ; and its train decreases in magnitude, until it reaches such a distance from the Earth, that the attenuated light of the Sun, which it reflects, ceases to make an impression on the organ of sight. Traversing unseen the remote portion of its orbit, the Comet wheels its etherial course far beyond the limits of the Solar System. What region it there visits, or upon what destination it is sent, the limited powers of man are unable to discover. After the lapse of years, we perceive it again returning to our System, and tracing a portion of the same orbit round the Sun, which it had formerly described.

Various opinions have been entertained by Astronomers respecting the tails of Comets. These tails or trains, sometimes occupy an immense space in the Heavens. The Comet of 1681, stretched its tail across an arch of 104 degrees ; and the tail of the Comet of 1769 subtended an angle of 60 degrees at Paris, 70 at Bologna, 97 at the Isle of Bourbon, and 90 degrees at

Sea, between Teneriffe and Cadiz. These long trains of light are maintained by Newton, to be a thin vapor, raised by the heat of the Sun from the Comet.

If we knew their uses in our System, we could form more probable conjectures as to the chronology of their creation. They have been noticed from the earliest era of our Astronomical History, and if our modern Philosophers had not discovered, that some (at least,) leave us to return again into our System, and therefore describe a vast elliptical orbit round our Sun, we might have fancied that the periods of their first recorded appearances in our field of science, were the eras of their individual formation. But their recurring presence proves, that their first existence ascends into unexplored and unrecorded antiquity. Yet, from whence they came to us, we as little know as for for what purpose. Tycha Brache proved that they were further from the Earth than the Moon, and were nearly as distant as the planets. The Comet of 1682, re-appeared in 1759, in the interval described, an orbit in the form of an ellipsis, answering to a revolution of 27,937 days. It will therefore re-appear in November, 1835. In its greatest distance, it is supposed not to go above twice as far as Uranus. This is indeed a prodigious sweep of space, and it has been justly observed, that the vast distance to which some Comets roam, proves how very far the attraction of the Sun extends; for though they stretch themselves to such depths in the abyss of space, yet by virtue of the Solar power, they return into its effulgence. But it has been recently discovered, that three Comets (at least,) never leave the planetary system. One whose period is three years and a quarter, is included within the orbit of Jupiter; another of six years and three quarters, extends not so far as Saturn; and a third of twenty years, is found not to pass beyond the circuit of Uranus.

The transient effect of a Comet passing near the Earth, could scarcely amount to any great convulsion, but if the Earth were actually to receive a shock by collision, from one of those bodies, the consequences would be awful. A new direction would be given to its rotatory motion, and the Globe would revolve around a new axis. The Seas, forsaking their ancient beds, would be hurried by their centrifugal force to the new equatorial regions; islands and continents, the abodes of men and animals, would be covered by the universal rush of the waters to the new Equator, and every vestige of human industry and genius at once destroyed.

Although the orbits of all the planets in the Solar System be crossed by five hundred different Comets, the chances against such an event however, are so very numerous, that there need be no dread of its occurrence; besides, that Almighty arm which first created them, and described for them their various orbits—that Omnipotent Wisdom which directed the times of their periodical revolutions, still continues to guide and protect all the workmanship of his hands.

Interrogations for Section Second.

Of what does the SOLAR SYSTEM consist?

What planets finish their circuits soonest?

Which moves with the greatest rapidity?

In what direction do they move in their orbits?

What is the form of the orbits described by the planets?

Where is the Sun placed?

In what time does he turn round on his own axis?

How is that proved?

What is his diameter?

What is his mean apparent diameter as seen from the Earth?

How is his solidity calculated?

What is the Ecliptic?

What is meant by the Nodes?

Which is the Ascending Node?

Which is the Descending Node?

How many signs are they asunder?

What additional Astronomical discoveries were made in the year 1805?

What planet is nearest the Sun?

What reasons are given to suppose that this planet receives its light from the Sun?

What is the computed distance of Mercury from the Sun?

What is its diameter?

In what time does it perform a revolution around the Sun?

What time on its own its axis?

How many miles does it move in an hour in its motion round the Sun?

How many degrees is his orbit inclined towards the Ecliptic?

What planet is next to Mercury?

What is the distance of this planet from the Sun?

How many miles in an hour, does Venus move in performing her revolution round the Sun?

In what time does she perform her annual revolution?

In what time does she perform a revolution on her axis?

What is her diameter?

How is it known that the orbits of Mercury and Venus are included within that of the Earth?

How many degrees at most does Mercury depart from the Sun?

How many Venus?

What is meant by inferior conjunction?

What is a transit?

What is the name of the third planet from the Sun?

What is its distance from the Sun?

What is its diameter?

In what time does it perform a revolution around the Sun?

What is its hourly progress?

In what time does it perform a revolution on its axis?

What is its form?

How many miles difference in the two diameters ?

What is the Moon ?

In what time does she perform a revolution round the Sun ?

Around the Earth ?

Around her own axis ?

What is her distance from the Earth ?

How many miles in diameter ?

What is her mean apparent diameter as seen from the Earth ?

Do the orbits of the Earth and Moon coincide ?

How much more light does the Earth give to the Moon, than the Moon gives to us ?

What is the name of the fourth planet from the Sun ?

What is his distance from that luminary ?

In what time does he perform his annual revolution ?

What is his hourly progress ?

What time his revolution on his axis ?

What is his mean apparent diameter as seen from the Earth ?

What as seen from the Sun ?

For what is the planet Mars remarkable ?

What have Astronomers concluded to be the cause of this remarkable appearance ?

What is its form ?

What is the name of the fifth planet from the Sun ?

By whom was it discovered ? And when ?

In what sign of the Ecliptic can this planet be seen without the aid of a telescope ?

What is its distance from the Sun ?

What is its diameter ?

What is the name of the sixth ?

By whom was it discovered ? And when ?

What is its color ?

For what is it distinguished ?

What is its distance from the Sun ?

What is the time of its tropical revolution ?

What is its diameter ?

What is its apparent diameter as seen from the Sun ?

What is the name of the seventh ?

By whom was it first discovered ?

In what year ?

What is the height of its atmosphere ?

In what time does this planet perform its revolution round the Sun ?

What is her distance from that luminary ?

What is the name of the eighth planet from the Sun ?

When was it discovered ? And by whom ?

What is its distance from the Sun ?

In what time does it perform its annual revolution around him ?

What is the height of its atmosphere ?

By what name are the last four collectively called ?

They are called Asteroids.

What is the name of the ninth planet from the Sun ?

How many miles distant from the Sun ?

What is his diameter ?

In what time does he perform his annual revolution ?

In what time on his own axis ?

What is his mean motion in his orbit ?

What is his mean motion on his axis?

Have the inhabitants of Jupiter any sensible change of seasons?

How many miles constitute a degree on this planet?

How many miles difference between his equatorial and polar diameters?

Why is this great difference?

How many degrees is the orbit of Jupiter inclined to the Ecliptic? In what sign of the Zodiac is his north node? In what sign his south node?

How many satellites attend this planet? What is his apparent diameter as seen from the Sun? What as seen from the Earth?

Of what benefit have those Moons been to the inhabitants of this Earth? Can either of them be seen by us without the aid of telescopes?

What name is given to the next, or tenth planet from the Sun?

What is its distance from the Sun?

How many miles does this planet move in an hour?

In what time does it perform its revolution around the Sun? In what time on its own axis?

What is its diameter?

What is his mean apparent diameter as seen from the Sun? What as seen from the Earth?

How many degrees is its axis inclined to its orbit?

What encircles his body?

How does it appear when viewed with a telescope?

What is its breadth?

How does it appear to the inhabitants of Saturn?

Why is it sometimes invisible to us ?

How many times does it appear in one revolution of the planet ?

In what signs and degrees of the Ecliptic does it disappear ?

In what signs and degrees does this ring appear most open ?

How many Satellites has this planet ?

Where are they situated, inside or outside of the ring ?

What is the form of this planet ?

What is the name of the next, or outermost planet ?

When was it discovered ?

How far is it situated from the Sun ?

In what time does it perform its annual revolution ?

What is its diameter ?

What is its apparent diameter as seen from the Sun ? What as seen from the Earth ?

Can it be seen without the aid of a telescope ?

How many Satellites attend it ?

In what direction do those Satellites move ?

What are Comets ?

In what direction do they move ?

In what part of its orbit is its train most brilliant ?

What was Newton's opinion concerning the Comet's tail, or train ?

How many Comets are supposed to belong to the Solar System ?

How many are known not to exceed the circuit of Uranus ?

What would be the result if a Comet should come in actual collision with this Earth ?

Is it probable that there will ever be such an occurrence ?

Why is it not probable ?

SECTION THIRD.

ON GRAVITY.

The power by which bodies fall towards the Earth, is Called Gravity, or Attraction. By this power in the Earth, it is that all the bodies on whatever side, fall in lines perpendicular to its surface. On opposite parts of the Earth, bodies fall in opposite directions, all towards the centre, where the whole force of gravity appears to be accumulated. By this power constantly acting on bodies near the Earth, they are kept from leaving it, and those on its surface are kept by it, that they cannot fall from it. Bodies thrown with any obliquity, are drawn by this power from a straight line into a curve, until they fall to the ground. The greater the force with which they are projected, the greater is the distance they are carried before they fall. If we suppose a body carried several miles above the surface of the Earth, and there projected in an horizontal direction, with so great a velocity that it moves more than semidiameter of the Earth in the line, it would take to fall to the Earth by gravity, in that case, if there were no resisting medium, the body would not fall to the Earth at all; but continue to circulate round the Earth, keeping always the same path, and returning to the point from whence it was projected with the same velocity with which it moved at first. We find that the Moon therefore must be acted upon by two powers, one of which would cause her to move in a right line, another bending her motion from that line into a curve. This attractive power must be seated in the Earth, for there is no other body within the Moon's orbit to draw her.* The attractive power of the Earth therefore extends to the Moon, and in combination with her projectile force, causes her to move round the Earth in the same manner, as the circulating body above supposed.

The Moons of Jupiter, Saturn and Herschel, are observed to move around their primary planets; therefore there is an attractive power in these planets, operating on their Satellites in the same manner, as the attraction of the Earth operates on the Moon. All the planets and Comets move round the Sun, and respect it as their centre of motion, therefore the Sun must be endowed with an attracting power, as well as the

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* If the Moon revolves in her orbit in consequence of an attractive power residing in the Earth, she ought to be attracted as much from the tangent of her orbit in a minute, as heavy bodies fall at the Earth's surface in a second of time. It is accordingly found by calculation, that the Moon is deflected from the tangent 16,09 feet in a minute, which is the very space through which heavy bodies descend in a second of time at the Earth's surface.

Earth and planets. Consequently all the bodies, or matter of the Solar System are possessed of this attractive power, and also all matter whatsoever.

As the Sun attracts the planets with their Satellites, and the Earth the Moon, so the planets and Satellites re-attract the Sun, and the Moon the Earth. This is also confirmed by observation; for the Moon raises tides in the Ocean; the satellites and planets disturb each other's motions. Every particle of matter being possessed of an attracting power, the effect of the whole must be in proportion to the quantity of matter in the body.

Gravity also, like all other virtues, or emanations, either drawing or impelling a body towards a centre, decreases as the square of the distance increases; that is, a body at twice the distance, attracts another with only a fourth part of the force; at four times the distance, with a sixteenth part of the force.

By considering the law of gravitation which takes place throughout the Solar System, it will be evident that the Earth moves round the Sun in a year. It has been stated and shown, that the power of gravity decreases as the square of the distance increases, and from this it follows with mathematical certainty, that when two or more bodies move round another as their centre of motion, the squares of the time of their periodical revolutions, will be in proportion to each other, as the cubes of their distances from the central body.—This holds precisely with regard to the planets round the Sun, and the satellites round their primaries, the relative distances of which are well known.

All Globes which turn on their own axis, will be oblate spheroids, that is, their surfaces will be further from their centres in the equatorial, than in the polar regions; for as the equatorial parts move with greater velocity, they will recede farthest from the axis of motion, and enlarge the equatorial diameter. That our Earth is really of this figure, is demonstrable from the unequal vibrations of a pendulum, and the unequal length of degrees in different latitudes.

Since then the Earth is higher at the equator than at the poles, the Seas naturally would run towards the polar regions, and leave the equatorial parts dry, if the centrifugal force of these parts, by which the waters were carried thither, did not keep them from returning. Bodies near the poles are heavier than those nearer the Earth's centre, where the whole force of the Earth's attraction is accumulated. They are also heavier, because their centrifugal force is less on account of their diurnal motions being slower. For both these reasons, bodies carried from the poles towards the Equator, gradually lose part of their weight.

Experiments prove that a pendulum which vibrates seconds near the poles, vibrates slower near the Equator, which shows that it is lighter, or less attracted there. To make it oscillate in the same time, it is found necessary to diminish its length. By comparing the different lengths of pendulums vibrating seconds at the equator, and at London; it is found that a pendulum must be 2,542 lines * shorter at the Equator than at the poles.

Interrogations for Section Third.

What is GRAVITY ?

Do falling bodies strike the surface of the Earth at right angles ?

Do falling bodies near the Earth, always direct their course to its centre ?

Where is the centre of Gravity situated ?

When bodies are projected in a right line, what brings them to the Earth ?

If there were no attractive power at the centre of the Earth, what would be the consequence were a body so projected, and not meeting any resistance from the air ?

We find that the Moon moves round the Earth in an orbit nearly circular. Why is it so ?

Where is that attractive power situated ?

Have the other planets attractive powers also ?

How is it known ?

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* A line is 1-12th part of an inch.

Where is the centre of attraction of the Solar System placed?

How is it known?

Do the planets attract the Sun as well as the Sun the planets?

Has every particle of matter an attractive power?

In what proportion does Gravity increase?

How far is the Moon deflected by Gravity from a tangent in one minute of time?

How far does a falling body descend in one second?

In what proportion are the squares of the times of the periodical revolutions of all the planets?

What will be the form all planets which revolve on their own axis?

Why will they be of that form?

How is it ascertained to a certainty, that our Earth is of that form?

Why are bodies near the poles heavier than those at the Equator?

Why is a pendulum vibrating seconds shorter at the Equator than at the poles?

What is the length of a pendulum vibrating seconds at the Equator?

Ans. 39,2 inches.

SECTION FOURTH.

PHENOMENA OF THE HEAVENS, AS SEEN FROM DIFFERENT PARTS OF THE EARTH.

The magnitude of the Earth is only a point when compared to the Heavens, and therefore every inhabitant upon it, let him be in any place on its surface, sees half of the Heavens. The inhabitant on the North Pole of the Earth, constantly sees the Northern Hemisphere, and having the North Pole of the Heavens directly over his head, his horizon coincides with the celestial Equator. Therefore all the Stars in the Northern Hemisphere, between the Equator and the North Pole, appear to turn round parallel to the horizon. The Equatorial Stars keep in the horizon, and all those in the Southern Hemisphere are invisible. The like phenomena are seen by an observer at the South Pole.—Hence, under either pole, only one half of the Heavens is seen; for those parts which are once visible never set, and those which are once invisible never rise.——

But the ecliptic or orbit, which the Sun appears to describe once a year by the annual motion of the Earth, has the half constantly above the horizon of the north pole; and the other half always below it. Therefore whilst the Sun describes the northern half of the ecliptic, he neither sets to the north pole, nor rises to the south; and whilst he describes the southern half, he neither sets to the south pole, nor rises to the north.—The same observations are true with respect to the Moon, with this difference only, that as the Sun describes the ecliptic but once a year, he is, during half that time, visible to each pole in its turn, and as long invisible.

But, as the Moon goes round the ecliptic in 27 days, 8 hours, she is only visible during 13 days and 16 hours, and as long invisible to each pole by turns.

All the planets likewise rise & set to the polar regions because their orbits are cut obliquely in halves by the horizon of the poles. When the Sun arrives at the sign Aries, which is on the twentieth of March, he is just rising to an observer on the north pole, and setting to another on the south pole.* From the Equator, he rises higher and higher in every apparent diurnal revolution, till he comes to the highest point of the ecliptic on the 21st of June, and then he is at his greatest altitude, which is 23 degrees and 28 minutes;

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* It is therefore evident when the Sun is on the Equator, an observer placed at each pole, sees about one half of the Sun above the horizon, and likewise an observer at the Equator discovers both poles in the horizon.

equal to his greatest north declination, and from thence he seems gradually to descend in every apparent circumvolution till he sets at the sign Libra, on the 23d September, and then he goes to exhibit the same appearances at the south pole for the other half of the year. Hence the Sun's apparent motion round the earth is not in parallel circles, but in spirals, such as may be represented by a thread wound round a globe from one tropic to the other. If the observer be any where on the terrestrial equator, he is in the plane of the celestial equator or under the equinox, and the axis of the earth is coincident with the plain of his horizon extended to the north and south poles of the Heavens. As the earth performs her diurnal revolution on her axis from west to east, the whole Heavens seem to turn round the contrary way. It is therefore plain that the observer at the equator has the celestial poles constantly in his horizon, and that his horizon cuts the diurnal paths of all the celestial bodies perpendicularly, and in halves. Therefore, the Sun, planets and stars rise every day, and ascend perpendicularly above the horizon for six hours, and passing over the meridian, descend in the same manner, for the six hours following, then set in the horizon and continue 12 hours below it; consequently the days and nights are equally long throughout the year. Thus we find, that to an observer at either of the poles, one half of the sky is always visible, and the other half never seen; but to an observer on the equator, the whole sky is seen every 24 hours. From the preceding observations, it is evident, that as the Sun advances from the equator to the tropic of Cancer, the days continually lengthen, and the nights shorten in the northern hemisphere, and the contrary in the southern; and when the Sun descends from the equator to the tropic of Capricorn, the days continually lengthen in the southern hemisphere, and the nights shorten; and the contrary in the northern.

The earth's orbit being elliptical, and the Sun constantly keeping in its lower focus, which is one million, three hundred and seventy-seven thousand miles from the middle point of the longer axis, the earth comes twice that distance, or 2,754,000 miles nearer the Sun* at one time of the year than at another; for the Sun appearing under a larger angle† in our winter than summer, proves that the earth is nearer the Sun in winter than in summer. The Sun is about 7 days longer in the northern hemisphere than in the southern in every year; and as the earth approaches near to the Sun, its motion is accelerated, and therefore goes over an equal space in less time, and as the earth recedes from the Sun, its motion is retarded in the same ratio that it was accelerated when in the southern hemisphere, and consequently requires a longer time to pass over an equal space.

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* The Sun is nearest to the Earth when he is on the tropic of Capricorn; farthest from it when he is on the tropic of Cancer.

† The nearer an object is to the eye, the larger it appears, and under the greater angle it is seen.

But here a question actually arises; why have we not the hottest weather when the earth is nearest to the Sun? In answer, it must be observed, that the eccentricity of the earth's orbit bears no greater proportion to the earth's mean distance from the Sun, than seventeen bears to a thousand, and therefore this small difference of distance cannot occasion any great difference of heat or cold.

But the principal cause of this difference is, that in winter, the same rays fall so obliquely upon us, that any given number of them is spread over a much greater portion of the earth's surface which we inhabit, and therefore each point must then have less rays than in summer. Also there comes a greater degree of cold in the long winter nights, than there can return of heat in so short days, and on both these accounts, the cold must increase. But in the summer season, the Sun's rays fall more perpendicularly upon us, aud therefore come with greater force, and in greater numbers on the same place, and by their long continuance, a much greater degree of heat is imparted by day than can fly off by night. It is for this reason that we have a greater degeee of heat in the month of September, than in the month of March; the Sun being on the equator in both these months, and consequently equally distant from the earth. Those parts which are once heated, retain the heat for some time, which, with the additional heat daily imparted, makes it continue to increase, though the Sun declines towards the south, and this is the reason why we have greater heat in July than in June. Also, we know that the weather is generally warmer at 2 o'clock in the afternoon, when the Sun has gone towards the west, than at noon, when he is on the meridian. Likewise those places which are well cooled, require time to be heated again, for the Sun's rays do not heat even the surface of any body till they have been sometime upon it, and therefore January is generally colder than December ; although the Sun has withdrawn from the winter tropic, and begins to dart his beams more perpendicularly upon us.

It was formerly the opinion of Philosophers, that the Sun was an immense mass of flame, and consequently the nearer we approached, the greater must be the heat. It is stated that the heat of the planet Mercury is seven times as great as ours, judging from his nearness to the Sun,and likewise that the cold at the planets Jupiter, Saturn and Herschel, must be extreme, because they are placed at so great a distance from that luminary.

It is well known, that near the equator, the tops of the highest mountains are covered with perpetual snow, and that in a less distance than three miles above the surface of the earth, we come to the region of perpetual congelation, where neither ice nor snow would ever melt, although nearer the Sun than in the plane below. Therefore, the distance from the Sun is not the real cause of heat or cold. Dark spots have been seen upon the Sun's disk, from which it is generally concluded that the body of the Sun is dark and opaque, surrounded by a luminous atmosphere, which darts its rays with immense velocity, and by some chemical operation, performed in their passage through the atmosphere with which this earth is encircled, convey to us the sensation of heat. The solar observations of Dr. Wilson, first suggested the opinion, that the Sun was an opaque and solid body, surrounded with a luminous atmosphere, and the telescopes of Dr, Herschel have tended still farther to establish this opinion. The latter of these astronomers, therefore imagined, that the functions of the Sun, as the source of light might be performed by the agency of the external atmosphere, while the solar nucleus was reserved, and fitted for the reception of inhabitants. That the Sun may at the same time be the source of light and heat, and yet capable of supporting animal life is one of those conclusions, which we are fond of admitting without hesitation, and to cherish with peculiar complacency. The mind is filled with admiration of the wisdom of that Benign Benefactor, and swells with the most sublime emotions, when it conceives, that apparently the most inaccessible regions of creation are peopled with animated beings, and, that while the Sun is the fountain of the most destructive of all the elements, it is at the same time the abode of life and plenty. When the invention of the telescope enabled Astronomers to detect the striking resemblances between the different planets of the system, it was natural to conclude, that, as they were composed of similar materials, as they revolved around the same centre, and were enlightened by similar Moons, they were all intended by their wise Creator to be the region in which he chose to dispense the blessings of existence and intelligence to various orders of animated beings. The human mind cheerfully embraced this sublime view of creation, and guided by the principle, that nothing was made in vain; man extended his views to the remote corners of space, and perceived in every star that sparkles in the sky, the centre of a magnificent system of bodies, teeming with life and happiness, and displaying fresh instances of the power and beneficence of that Being who rolled such stupenduous orbs from his creating hand.

Having thus traversed the illimitable regions of space, and considering every world which rolls in the immense void as the scene on which the Almighty has exhibited his perfections, the mind, unable to command a wider range, rests in satisfaction on the faithful analogies which it has pursued.

Interrogations for Section Fourth.

How much of the Heavens does a spectator see placed at the north pole of the earth ?

What part if placed at the south pole ?

What part if seen at the equator ?

When placed at the north pole, how far south in the Heavens would his vision extend ?

If at the south pole, how far north would his vision extend ?

Does any part of the ecliptic, or orbit, which the Sun seems to describe once a year, appear above the horizon of the north pole ?

What signs of the ecliptic appear above the horizon of the north pole ?

Ans.--Aries, Taurus, Gemini, Cancer, Leo and Virgo; these are called northern signs.

What signs appear above the horizon of the south pole ?

Ans.—Libra, Scorpio, Sagitarius, Capricornus, Aquarius, and Pisces. These are called southern signs.

When the Sun is in any of the northern signs, does he ever set at the north pole, or rise at the south ?

When in the southern signs, does he ever set to the south pole, or rise to the north ?

Is it the same with the Moon ?

What is the length of the longest days at either of the poles ?

What the length of the longest nights ?

In what month of the year is the Sun on the tropic of Cancer, or highest point of his orbit ?

In what months on the tropic of Capricorn ?

In what months on the equator ?

When the Sun is in the equator, can he be seen at both poles ?

Is the Sun's apparent motion round the earth in circles ?

Are the whole Heavens visible every 24 hours at the equator ?

What is the form of the earth's orbit ?

How many miles is the earth nearer the Sun at one time of the year than at another ?

In what month in the year is it the nearest ?

In what month farthest off ?

How many days is the Sun longer in the northern hemisphere, than in the southern in every year ?

Why is itlonger north of the equator than south ?

Why have we not the warmest weather when nearest the Sun ?

What was the opinion of former Philosophers concerning the Sun ?

What the opinion of Dr. Herschel ?

How far above the surface of the earth at the equator, is the region of perpetual congelation ?

What is the prevailing opinion concerning the rays of the Sun producing heat ?

Is the body of the Sun supposed to be inhabited ?

With what is its dark opaque body surrounded ?

SECTION FIFTH.

PHYSICAL CAUSES OF THE MOTIONS OF THE PLANETS.

From the uniform projectile motion of bodies in straight lines, and the universal power of attraction which draws them off from these lines, the curvilineal motions of all the planets arise. If a body be projected in a right line in open space, and meeting with no resistance, it would continue forever to move with the same velocity, and in the same direction. But when this projectile force is acted upon by any attracting body, with a power duly adjusted, and perpendicular to its motion, it will then be drawn from a straight line and forced to revolve round the centre of attraction in a circular form. But when the projectile force first given exceeds the attracting force, the centrifugal force, or tendency to fly off in a tangent, is arrested by the attractive power, and therefore its velocity becomes continually more and more impeded, until the attractive power has acquired a greater influence, and then its motion becomes gradually accelerated with a tendency to approach nearer to its point of attraction, and consequently the moving body forms an elliptical orbit.

It is readily perceived, that, in two points in the orbit, the centripetal and centrifugal forces are equal, and that when its motion is both accelerated and retarded by the attractive power, it must of necessity pass over equal areas in the same space of time.

As the planets approach nearer the sun, and recede farther from him in every revolution, there may be some difficulty in conceiving the reason, why the power of gravity when it once obtains the victory over the projectile force, does not bring the planets continually nearer the sun in every revolution, till they fall upon and unite with him. Or why the projectile force when it once gets the better of gravity, does not continue to carry the planets farther from the sun, till it removes them quite out of the sphere of his attraction and go on in straight lines forever afterwards, or when the centripetal and centrifugal forces are equal, why it does not commence moving off in the form of a perferct circle. By considering the effects of these powers acting on each other according to the preceding description, the difficulty will be at once removed.

A double projectile force will always balance a quadruple power of gravity, and when a planet is put in motion by projectile force, whether the velocity with which it moves be rapid or slow, it is continually resisted by the attraction of the sun, and consequently moves, slower until the power of attraction has gained the ascendency; its motion then becomes accelerated by the centripetal power acting on the planet, until its velocity becomes equal to the projectile force with which it was first put in motion. Therefore it must continue to revolve in an elliptical orbit as before stated. And when these two forces are equal on the body in motion, they never act at right angles, but in such acute angles, that the planet is moving with such velocity, that the ascendency is instantly obtained. In order to make the projectile force balance the gravitating power so exactly, as that the body may move in a circle, the projectile velocity of the body must be such as it would have acquired by gravity alone, in falling through half the radius of the circle.

By the above mentioned law, bodies will move in all kinds of elliptical orbits whether long or short; if the spaces in which they move in the longer ellipses have so much the less projectile force impressed upon them in the higher parts of their orbits, and their velocities in coming down towards the sun, are so prodigiously increased by his attraction, that their centrifugal forces in the lower parts of their orbits are so great as to overcome the sun's attraction there, and cause them to ascend again towards the higher parts of their orbits; during which, the sun's attraction acting so contrary to the motions of those bodies, causes them to move slower and slower until the projectile forces are diminished, almost to nothing, and then they are again brought back by the sun's attraction as before.

If the projectile forces of all the planets (and likewise those comets, whose mean distances from the sun have been ascertained,) were destroyed at their mean distances from the sun; their gravities would bring them down, so that Mercury would fall to the sun in 15 days and 13 hours; Venus in 39 days and 17 hours; the Earth or Moon in 64 days and 10 hours; Mars in 121 days; Jupiter in 290 days; Saturn in 767 days; and Herschel in 5406 days; the nearest comet within the orbits of the planets in 13,000 days; the middlemost in 23,000 days, and the outermost in 66,000 days. The Moon would fall to the earth in 4 days and 20 hours, Jupiters first moon would fall to him in 7 hours; his second in 15 hours; his third in 30 hours; and his fourth in 71 hours.—Saturns first moon would fall to him in 8 hours, his second in 12 hours; his 3d in 19 hours; his 4th in 68 hours; his 5 in 336 hours. A stone would fall to the earth's centre if there were an hollow passage in 21 minutes and 9 seconds*.

The rapid motions of the moons of Jupiter and Saturn round their primaries, demonstrate that these two planets have stronger attractive power than the earth; for the stronger that one body attracts another, the greater must be the projectile force, and consequently the force of the other body must be increased to keep it from falling to its central planet. Jupiter's second moon is 124,000 miles farther from Jupiter than our Moon is from us; and yet this second Moon goes almost 8 times around Jupiter, whilst our Moon goes once round the Earth. What a prodigious attractive power must the Sun then have, to draw all the planets and satellites of the system towards him, and what an amazing power must it have acquired to put all these planets and moons into such rapid motions at first. Amazing indeed to us, because impossible to be effected by the united strength of all the created beings in an unlimited number of worlds, but in no wise hard for the Almighty, whose Planetarium takes in the whole Universe.

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* The squares of the times, that any planet would fall to the sun are as as the cubes of their distances: or multiply the time of a whole revolution by ,0176766 the product will be the time in which the planet would fall to the sun.

The Sun and planets mutually attract each other, the power by which they are thus attracted, is called Gravity. But whether this power be mechanical or not, is very much disputed. Observation proves that the planets disturb each other's motions by it, and that it decreases according to the squares of the distances of the Sun and planets; as great light which is known to be material, likewise does. Hence, Gravity should seem to arise from the agency of some subtle matter, pressing towards the Sun and planets, and acting like all mechanical causes, by contact. But when we consider that the degree or force of Gravity, is exactly in proportion to the quantities of matter in those bodies, without any regard to their magnitudes or quantities of surface, acting as freely on their internal as external parts, it appears to surpass the powers of mechanism, and to be either the immediate agency of the Deity, or affected by a law originally established and impressed on all matter by him. That the projectile force was at first given by the Deity, is evident ; since matter can never put itself in motion, and all bodies may be moved in any direction whatever, and yet the planets, both primary and secondary, move from west to east, in lines nearly coincident, while the Comets move in all directions, and in planes very different from each other ; these motions can be owing to no mechanical cause or necessity, but to the free will and power of an intelligent Being.

Whatever Gravity be, it is plain that it acts every moment of time ; for if its action should cease, the projectile force would instantly carry off the planets in straight lines from those parts of their orbits where Gravity left them. But the planets being once put in motion, there is no occasion for any new projectile force, unless they meet with some resistance in their orbits, nor for any mending hand, unless they disturb each other too much by their mutual attraction.

It is found that there are disturbances among the planets in their motions, arising from their mutual attractions, when they are in the same quarter of the Heavens, and the best modern observers find that our years are not always precisely of the same length.

If the planets did not mutually attract each other, the areas described by them would be exactly proportional to the times of description. But observations prove that these areas are not in such exact proportions, and are most varied when the greatest number of planets are in any particular quarter of the Heavens. When any two planets are in conjunction, their mutual attractions which tend to bring them nearer to each other, draws the inferior one a little nearer to him; by these means, the figure of their orbits is somewhat altered, but this alteration is too small to be discovered in several ages. By the most simple law, the diminuation of Gravity, as the square of the distance increases; the planets are not only retained in their orbits, when whirling with such immense velocity around their central Sun; but an eternal stability is insured to the solar system. The small derangements which affect the motions of the Heavenly bodies, are only apparent to the eye of the Astronomer, and even these after reaching a certain limit, gradually diminish, till the system regaining its balance, returns to that state of harmony, and order which has preceded the commencement of these secular irregularities. Even amidst the changes and irregularities of the system, the general harmony is always apparent; and those partial and temporary derangements, which vulgar minds may seem to indicate a progressive decay, serve only to evince the stability and permanency of the whole.

In contemplation of such a scene, every unperverted mind must be struck with that astonishing wisdom which framed the various parts of the Universe, and bound them together by one simple, yet infallible law. In no part of creation, from the smallest insect to the highest seraph, has the Supreme Architect of the Universe left himself without a witness; but it is surely in the Heavens above, that the Divine attributes are most gloriously displayed.

Interrogations for Section Fifth.

From what source do the circular motions of the planets arise ?

With what velocity would projected bodies continue to move if they met with no resistance ?

What is meant by the centrifugal force ?

What is meant by centripetal force ?

Are the centripetal and centrifugal forces ever equal while the planet performs its revolution round the Sun ?

When the power of Gravity exceeds the projectile force, why does it not draw the planets to the Sun ?

When the projectile, or centrifugal force exceeds the attraction, why does it not fly off, and never return ?

When these forces are equal, why do they not move in perfect circles ?

What will a double projectile force balance ?

In what case could the projectile be made to balance the gravitating power in such manner that the planets should move in a perfect circle ?

If the centrifugal forces should at once be destroyed, in what time would each of the planets fall to the Sun?

In what time would the Moon fall to the earth?

What rule for finding the time in which would they fall to the Sun?

What do the rapid motions of the Moons of Jupiter and Saturn demonstrate?

Do the Sun and planets continually attract each other?

Should gravity instantaneously cease, what would be the consequence?

Are the motions of the planets continually the same?

Do they continue to move exactly in the same path at every revolution?

By what simple law does gravity diminish?

SECTION SIXTH.

ON LIGHT AND AIR.

Light consists of exceedingly small particles of matter, issuing from a luminous body, as from a lighted candle. Such particles of matter constantly flow in every direction. By Dr. Neiwentyt's computation, 148,660,000,000,000,000,000,000,000,000,000,000,000,000,000 particles of light in one second of time flows from a candle, which number contains at least 6,337,245,000,000 times the number of grains of sand in the whole earth; supposing 100 grains of sand to be equal in length to an inch, and consequently every cubic inch of the earth to contain one million of such grains. These amazingly small particles, by striking upon our eyes, excite in our minds the idea of light, and if they were as large as the smallest particle of matter discernible by our best microscopes, instead of being serviceable to us, they would soon deprive us of sight by the force arising from their immense velocity, which is computed at nearly two hundred thousand miles in one second.*

When these small particles flowing from a candle, fall upon bodies, and are thereby reflected to our eyes, they excite in us the idea of that body, by forming its image on the retina. † Since bodies are visible on all sides, light must be reflected from them in all directions. A ray of light is a continued stream of these particles, flowing from any visible body in a straight line. That the rays move in straight, and not in crooked lines, (unless they be refracted,) is evident from bodies not being visible if we endeavor to look at them through the bore of a bended pipe; and from their ceasing to be seen by the interposition of other bodies, as the fixed stars, by the interposition of the Moon and planets and the Sun wholly, or in part, by the inter position of the Moon, Mercury or Venus.

There is no physical point,(says Melville,) in the visible horizon which does not send rays to every other point; no star in the Heavens, which does not send light to every other star. The whole horizon is filled with rays from every point in it; and the whole visible Universe with a sphere of rays from every star. In short, for any thing we know, there are rays of light joining every two physical points in the Universe, and that in contrary directions, except when opaque bodies intervene. A ray of light coming from any of the fixed stars to the human eye, has to pass in every part of the intermediate space between the point from which it has been projected, and our solar system, through rays of light flowing in all directions from every fixed star in the Universe, and in reaching this earth; it has passed across the whole ocean of the solar light, and that which is emitted from the planets, satellites and comets. Yet in this course, its progress has not been intercepted.

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* Light passes from the Sun to the Earth in 8 minutes and 7 seconds, which is 195,072 miles in one second of time.

† A fine net work membrane, in the bottom of the eye.

The densities and quantities of light, received upon any given plane, are diminished in the same proportion, as the squares of the distances of that planet from the luminous body are increased; and on the contrary, are increased in the same proportion as these squares are diminished.

When a telescope magnifies the disk of the Moon, and planets, they appear more dim than to the bare eye; because the telescope cannot increase the quantity of light in the same proportion that it can magnify the surface, and by spreading the same quantity of light over a given surface, it appears more dim, than when beheld with the naked eye.

When a ray of light passes out of one medium into another, it is refracted, or turned out of its course more or less, as it falls more, or less obliquely on the refracting surface which divides the two mediums.

This may be proved by several experiments. In a basin, place a piece of money, or any metalic substance, and then retire from it till the edge of the basin hides the money from your view, then keeping your head steady, let another pour water gently into the basin, and as the basin fills with the water, more and more of the substance of the bottom will come in sight, and when the basin is filled, the substance at the bottom will be full in view, and appear as if it was lifted up; for the ray which was straight while the basin was empty, is now bent at the surface of the water, and turned out of its natural course into an angular direction, and the more dense the medium is, the more light is reflected in passing through it.

The earth is surrounded by a thin fluid mass of matter, called the AIR, or ATMOSPHERE, which gravitates to the earth, revolves with it in its diurnal motion, and goes with it round the Sun every year. This fluid is of an elastic and springy nature, and that part next the earth being compressed by the weight of all the air above it, is pressed close together, and therefore is the most dense at the surface of the earth, and gradually rarer the higher you ascend.

It is well known, that the air near the surface of our earth possesses a space about nine hundred times greater than water of the same weight, and therefore a cylindric column of air nine hundred feet high, is of equal weight with a cylinder of water of the same diameter one foot high. But a cylinder of air reaching to the top of the atmosphere, (45 miles,) is of equal weight with a cylinder of water about 33 feet high, and therefore, if from the whole cylinder of air, the lower part of nine hundred feet high, is taken away, the upper part remaining, will be of equal weight with a cylinder of water 32 feet high. Therefore. at the height of nine hundred feet, the weight of the incumbent air is less, and consequently the rarity of the compressed air is greater, than near the earth's surface in the ratio of 33 to 32.

The weight of the air at the earth's surface, is found, by experiments made with the air pump, and also by the quantity of mercury that the atmosphere balances in the barometer, in which, at a mean state, the mercury stands 29 and ½ inches high. And if the tube were a square inch at the base, and of equal size to the top, it would, at that height, contain 29 and ½ cubic inches of mercury; which is just fifteen pounds, and consequently every square inch of the surface of the earth, sustains a weight of 15 pounds; every square foot 2,160 pounds, at this ratio, and when the mercury is at that height in the barometer, every common sized man sustains a weight of 32,400 pounds, (the area of the surface of his body being about 15 square feet) of air all round; for fluids press equally up and down, and on all sides. But because this enormous weight is equal on all sides, and counterbalanced by the spring of the air diffused through all parts of our bodies, it is not in the least degree felt by us.

The state of the air is such many times, that we feel ourselves languid and dull, which is generally thought to be occasioned by the air's being foggy and heavy about us. But at such times, the air is too light. The truth of this assertion, is known by the sinking of the mercury in the barometer, and at these times, it is generally found that the air has not sufficient strength to bear up the vapors which compose the clouds; for when it is otherwise the clouds ascend high, and the air is more elastic and weighty about us, and by these means, it balances the internal spring of the air within us, braces the nerves and blood vessels, and makes us brisk and lively.

It is entirely owing to the state of the atmosphere, that the Heavens appear bright even in the day time. For, without an atmosphere, only that part of the Heavens would shine in which the Sun was placed, and if we could live without air, and should turn our backs towards the Sun, the whole Heavens would appear as dark as in the night; and the stars would be seen as clearly as in the nocturnal sky. In this case, we should have no twilight, but a sudden transition from the brightest sunshine to the darkness of night, immediately after Sun-set, and from the blackest darkness to the brightest Sun-shine at Sun-rising.

But, by means of the atmosphere, we enjoy the Sun's light reflected from the aerial particles for some time before he rises, and after he sets. When the earth by its rotation, has withdrawn our sight from the Sun, the atmosphere, (being still higher than we,) has the Sun's light imparted to it which gradually decreases until he has descended 18 degrees below the horizon, and then all that part of the atmosphere which is above us is dark. From the length of twilight, Dr. Heill has calculated the height of the atmosphere (so far as it is sufficiently dense to reflect any light,) to be about forty-four miles high. But it seldom is sufficiently dense at two miles height to bear up the clouds.

The atmosphere refracts the rays so as to bring him in sight every clear day before he rises in the horizon, and to keep him in view for some minutes after he is really set below it. For, at some times of the year, we see the Sun ten minutes longer above the horizon than he would be, if there were no refractions, and about six minutes every day, at a mean rate.

Interrogations for Section Sixth.

Of what does LIGHT consist ?

What would be the consequence, if the particles of light were sufficiently large to be discovered by our best microscopes.

What is meant by the retina ?

Is light reflected in all directions ?

What is a ray of light ?

How is it ascertained that rays of light move in direct lines ?

Is light reflected from the Moon to our Earth ?

Is light sent from one star to another ?

In what time does light pass from the Sun to the Earth ?

How many miles per second is its velocity ?

Are the rays of light passing from any luminous body, interrupted by those from any other ?

Are the quantities of light received upon any given plane, diminished by being removed at a greater distance from that plane ?

In what proportion are they diminished ?

What appearance have the moons or planets, when their disks are magnified by the aid of a telescope ?

When a ray of light passes out of one medium into another, is it turned out of its former course ?

If it does, how can it be proved?

With what is the earth surrounded?

What is the nature of this fluid?

Is it capable of being compressed?

Is it more dense at the surface of the earth, than some distance above?

How much heavier is water than atmospheric air?

What is the mean height of the atmosphere?

By what means is the weight of air at the surface of the earth, found?

What is the weight of air on every square inch?

How many pounds on a square foot?

How many on the surface of the body of a common sized man?

In what kind of weather is the air lightest?

How is it proved?

In what kind the heaviest?

At what height may the clouds be borne by the density of the atmosphere?

How is air rarified?

By what is the Sun discovered, when he is in reality below the horizon?

SECTION SEVENTH.

TO FIND THE DIAMETER OF THE EARTH, AND THE DISTANCES OF THE SUN AND MOON, AND THE DISTANCES OF ALL THE PLANETS FROM THE SUN.

It has been observed that a person at Sea, and exactly under the equator, discovers both the north and south polar stars, just rising in the horizon. Therefore as you advance towards either pole, the star will appear to rise higher in the horizon, and if you advance ten degrees from the equator towards the north pole, the polar star will there be ten degrees above the horizon, and consequently, if the angle of the elevation of that star be taken at any place, the number of degrees of its elevation, will be equal to the north latitude of the place where the elevation was taken. It has been ascertained by actual measurement, that one degree of the surface of the earth contains 69 and ½

NOTE—Persons unacquainted withTrigonometry, may pass over this Section, as they will not be capable of forming correct ideas of the methods of finding the accurate distances, and therefore must take the Philosopher's word.

miles nearly. Then, as one degree is to 69 and ½ miles, so is 360 degrees to the circumference of the earth. The diameter can then be found by the following proportion; as 355 is to the circumference, so is 113 to the diameter.

Let a large graduated instrument having a moreable index, with sight holes, be prepared, in such manner, that its plane surface may be parallel to the plane of the equator, and its edge in the meridian, so that when the Moon is in the equinox, and on the meridian, she may be seen through the sight holes when the edge of the moveable index cuts the beginning of the divisions on the graduated limb, and when she is so seen, let the precise time be noted. As the Moon revolves about the earth from any meridian to the same again in 24 hours and 48 minutes, she will go a fourth part round it in a fourth part of that time; namely six hours and 12 minutes as seen from the earth's centre or pole: But, as seen from the observer's place on the earth's surface, the Moon will seem to have gone a quarter round the earth, when she comes to the sensible horizon; for the index through the sights of which she is then viewed, will be 90 degrees from where it was when she was first seen. Let the exact moment when she is in, or near the sensible horizon be carefully noted,* that it may be known in what time she has gone through 90 degrees, as seen by the observer on the surface; subtract this time, from the aforesaid six hours and 12 minutes, and the remainder is the time that she is moving in her orbit, from a tangent, touching the earth's surface, to a parallel line drawn from the earth's centre; which affords an easy matter of finding the Moon's horizontal parallax, which is equal to an angle made between the last mentioned line, and another drawn from the observer to the centre of the Moon, as seen from the centre of the earth or poles.—Then, as the afore mentioned remainder is to 90 degrees, so is 6 hours 12 minutes, to the number of degrees which measures the arc; subtract 90 degrees from this arc, and the remainder is the angle under which the earth's semi-diameter is seen from the Moon. Since all the angles of a right angled triangle are equal to two right angles, or 180 degrees, and the sides of a plain triangle are always proportionate to the sines of their opposite angles; say, (by Trigonometry,) as the sine of the angle at the Moon, is to the earth's semi-diameter, so is radius, (or sine of 90 degrees,) to its opposite side; which is the distance from the observer to the Moon, or subtract the angle at the Moon from 90 degrees, then say as the angle at the Moon, is to the earth's semi-diameter, so is this remainder, to the distance from the centre of the earth to the Moon; which comes out at a mean rate 240 thousand miles. The Sun's distance from the earth might be found in the same manner, if his horizontal parallax were not so small as to be hardly perceptible, being 8,63 seconds,* while the horizontal parallax of the Moon is 57 minutes and 18 seconds. Therefore, to find the distance to the Sun, say by single proportion, as the Sun's horizontal parallax, (8,63 seconds,) is to the distance that the Moon is from the earth, (240,000 miles,) so is the Moon's horizontal parallax, (57 minutes and 18 seconds,) to the distance of the Sun from the earth, which gives in round numbers, 95 millions of miles.

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* Here proper allowances must be made, (for the refraction being about 33 minutes of a degree in the horizon,) will cause the Moon's centre to appear 33 minutes above the horizon. when her centre is really in it.

The Sun and Moon appear nearly of the same size as viewed from the earth, and every person who understands Trigonometry, knows how their true magnitudes may be ascertained from the apparent, when their true distances are known.

Spheres are to each other, as the cubes of their diameters. Whence, if the Sun be 95 millions of miles from the earth, to appear of equal size with the Moon, whose distance is only 240 thousand; he must in solid bulk, be 62 millions of times larger than the Moon.

The horizontal parallaxes are best observed at the equator; Because the heat is so nearly equal every day, that the refractions are almost constantly the same, and likewise, because the parallactic angle is greater there; the distance from thence to the earth's axis, being greater than upon any parallel of latitude.

The earth's distance from the Sun being determined, the distances of all the other planets are easily found by the following analogy; their periodical revolutions around him, being obtained by observation.—As the square of the earth's period round the Sun,is to the cube of its distance from that luminary, so is the square of the period of any other planet, to the cube of its distance, in such parts or measures, as the earth's distance was taken. This proportion gives the relative mean distances of the planets from the Sun to the greatest degree of exactness.

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* Ascertained from the transits of Venus across the Sun's disk, in the years 1761 and 1769.

The earth's axis produced to the stars, and being carried parallel to itself during the earth's annual revolution, describes a circle in the sphere of the fixed stars, equal to the earth's orbit. This orbit, though very large, would seem to be no larger than a point, if it were viewed from the stars, and consequently, the circle described in the sphere of the stars, by the axis of the earth, produced, if viewed from the earth, must appear as a point; its diamater appears too little to be measured by observation.

Dr. Bradley has assured us, that if it had amounted to a single second, or two at most, he should have perceived it in the great number of observations he has made; especially upon Draconis, (a star of the third magnitude,) and that it seemed to him very probable that the annual parallax of this star, is not so great as a single second, and consequently that it is more than four hundred thousand times further from us than the Sun. If we suppose that the parallax of the nearest fixed star is one second, and that the mean distance of the earth from the Sun, is 95 millions of miles, we shall have a right angled triangle whose vertical angle is one second, and whose base is 95 millions of miles to find its side, or distance of the star; which would exceed 20 billions of miles, a distance through which light although travelling at the rate of two hundred thousand miles in a second, could not pass in three years. If the brightest star in the Heavens is placed at such an immense distance from our system, what an immeasureable interval must lie between us and those minute stars, whose light is scarcely visible by the aid of the most powerful telescopes. Many of them are, perhaps so remote, that the first beam of light which they sent forth at their creation, has not yet arrived within the limits of our system. While other stars which have disappeared, or have been destroyed for many centuries, will continue to shine in the Heavens till the last ray which they emitted, has reached the earth which we inhabit.

The mean distances of the planets from the Sun, and their apparent diameters as seen from that luminary, being found, the diameters of all the planets can be ascertained by Trigonometry; thus—Subtract the angle or apparent diameter of the planet as seen from the sun, from 180 degrees, and half the remainder will be the angle at the disk of the planet; then as the sine of the angle at the disk is to the distance of the planet from the Sun, so is half the angle at the Sun to the semi-diameter of the planet.

The small apparent motion of the stars discovered by that great Astronomer, (Dr. Bradley,) he found to be owing to the aberation of their light, which can result from no known cause, except that of the earth's annual motion, as it agrees so exactly therewith, it proves beyond dispute that the earth has such a motion; for this aberation completes all its various phenomena every year, and proves that the velocity of star-light is such as carries it through a space equal to the Sun's distance from us, in eight minutes and seven seconds of time. Hence the velocity of light is about 10,313 times as great as the earth's velocity in its orbit, and consequently nearly two hundred thousand miles in one second of time.

Interrogations for Section Seventh.

From what place can the North and South Poles both be seen ?

Where will they appear ?

What is an angle of elevation ?

Suppose the north polar star is elevated 43 degrees above the horizon, what is your degree of latitude ?

How many miles constitute a degree on the surface of the earth ?

How is that known ?

How many degrees in a circle ?

How is the circumference of the earth found ?

How the diameter ?

In what time does the Moon revolve about the earth from any meridian to the same again ?

What is meant by the Moon's horizontal parallax ?

How is the distance to the Moon found ?

How is the distance to the Sun found ?

What proportions do solid bodies bear to each other ?

When the distance from the earth to the Sun is found, how is the distance from the Sun to the other planets ascertained ?

By what method are the periodical revolutions of the planets ascertained ?

How are the periods ascertained of their revolutions on their own axis ?

Why cannot the exact distance to the fixed stars be found ?

How are the diameters of the planets ascertained ?

How the diameter of the Sun ?

SECTION EIGHTH.

OF THE EQUATION OF TIME, AND PRECESSION OF THE EQUINOXES.

The Stars appear to go around the earth in 23 hours 56 minutes and 4 seconds, and the Sun in 24 hours. So that the stars gain 3 minutes and 56 seconds upon the Sun every day; which amounts to one diurnal revolution in a year, or 365 days, as measured by the returns of the Sun to the meridian; there are 366 days as measured by the stars returning to it. The former are called solar days; the latter sydereal.

The earth's motion on its axis being perfectly uniform, and equal at all times of the year; the sydereal days are always precisely of an equal length, and so would the solar days be if the earth's orbit were a perfect circle, and its axis perpendicular to it. But the earth's diurnal motion on an inclined axis, and its annual motion in an elliptical orbit, cause the Sun's motion in the Heavens to be unequal ; for sometimes he revolves from the meridian to the meridian again in somewhat less than 24 hours; shewn by a well regulated clock, and at other times in somewhat more ; so that the time shown by a true going clock, and true Sun-dial is never the same ; except on the 15th day of April, the 16th of June, the 31st of August, and the 24th day of December, The clock, if it goes equally true during the whole year, will be before the Sun from the 24th of December till the 15th of April; from that time till the 16th of June, the Sun will be faster than the clock.

The point where the Sun is at his greatest distance from the earth is called the Sun's apogee. The point where he is at his least distance from the earth is called his perigee ; and a straight line drawn through the earth's centre from one of those points to the other is called the line of the apsides.

The distance that the Sun has gone in any time from his apogee, is called his mean anamoly, and is reckoned in signs, degrees, minutes and seconds, allowing 30 degrees to a sign.

OF THE PRECESSION OF THE EQUINOXES.

It has been observed, that by the earth's motion on its axis, there is more matter accumulated around the equatorial parts than any where else, on the surface of the earth. The Sun and Moon, by attracting this redundency of matter, bring the equator sooner under them in every return towards it, than if there were no such accumulation. Therefore if the Sun sets out as from any star, or other fixed point in the Heavens, the moment when he is departing from the equatorial, or from either tropic, he will come to the same equinox or tropic again 20 minutes and 17 and ½ seconds of time, or 50 seconds of a degree, before he completes his course so as to arrive at the same fixed star, or point from whence he set out. For the equinoxial points recede 50 seconds of a degree westward every year, contrary to the Sun's annual progessive motion.

When the sun arrives at the same equinoxial,* or solstitial point, he finishes what is called the tropical year; which by observation is found to contain 365 days, 5 hours, 48 minutes, and 47 seconds, and when he arrives at the same fixed star again, as seen from the earth, he completes the sydereal year, which contains 365 days, 6 hours, 9 minutes 14 and ½ seconds.

The sydereal year is therefore 30 minutes 17 and ½ seconds longer than the solar, or tropical year, and 9 minutes, 14 and ½ seconds longer than the Julian or civil year; which we state at 365 days, 6 hours.

As the Sun describes the whole ecliptic, or 360 degrees in a tropical year, he moves 59 minutes, 8 seconds of a degree every day, at a mean rate ; therefore he will arrive at the same equinox or solstice, when he is 50 seconds of a degree short of the same star or fixed point in the Heavens, from which he set out in the year before. So that with respect to the fixed stars, the Sun and equinoxial points fall back 30 degrees in 2,160 years, which will make the stars appear to have gone 30 degrees forward with respect to the signs of the ecliptic in that space of time ; for the same signs always keep in the same points of the ecliptic, without regard to the constellations.

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* The two opposite points in which the ecliptic crosses the equinox are called the equinoxial points, and the two points where the ecliptic touches the tropics, (which are likewise opposite, and 90 degrees from the tropic,) are called the solstitial points.

The Julian year exceeds the solar by 11 minutes and 3 seconds, which in 1,438 years amount to eleven days, and so much our seasons had fallen back with respect to the days of the months since the time of the Nicene Council, in A. D. 325, and therefore to bring back all the feasts and festivals to the days then settled, it was requisite to suppress 11 nominal days.*-- And that the same seasons might be kept to the same time of the year, for the future to leave out the bissextile day in February, at the end of every century, not divisible by four, reckoning them only common years, as the 17th, 18th, and 19th centuries; namely, the years 1700, 1800, and 1900, &c. because a day intercalated every fourth year was too much, and retaining the bissextile at the end of those centuries of years which are divisible by four, as the years 1600, 2000, 2400, &c. otherwise in length of time, the seasons would be quite reversed with regard to the months of the year; though it would have required near 23,783 years to have brought about such a total change. If the earth had exactly made 365 and $\frac{1}{4}$ diurnal revolutions on its axis, whilst it revolved from any equinoxial or solstitial point to the same again, the civil and solar years would always have kept pace together, and the style would never have needed any alteration.

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* The difference in the present century, between the old and new styles, is twelve days.

Interrogations for Section Eighth.

In what time do the stars appear to go round the Earth?

In what time does the Sun appear to go round the Earth?

In what time do the stars gain one revolution?

How many days in a solar year?

How many in a sydereal?

Is the motion of the earth on its own axis uniform at all times of the year?

Are the sydereal days always of the same length?

Is the Sun's apparent diameter in the Heavens always equal?

On what days of the year are the Sun and clock together?

Between what periods will the clock be before the Sun?

Between what periods will the Sun be before the clock?

What is called the Sun's apogee?

What his perigee?

What the line of the Apsides?

What is meant by the Sun's mean anamoly?

How is his mean anamoly reckoned ?

What is meant by the precession of the equinoxes ?

Is there more matter accumulated at the equator than at any other part of the earth ?

What is the cause of such accumulation ?

What is the Equator ?

What effect is produced by this accumulation of matter ?

How many seconds of a degree do the equinoxial points recede westward every year ?

What are meant by the equinoxial points ?

What the solstitial ?

Which is the longest, the sydereal or solar year, and how much ?

How many degrees will the equinoxial points fall back in 2,160 years ?

Do the same signs always keep in the same points of the ecliptic ?

Which is the longest, the Julian or the solar year, and how much ?

How many days difference will this make in 1.433 years ?

In what year of the Christian era was the Council of Nice held ?

What centuries were to be leap years ?

What is the difference between the old and new styles in the present century ?

SECTION NINTH.

OF THE MOON'S PHASES.

By looking at the Moon with an ordinary telescope, we perceive that her surface is diversified with long tracts of prodigious high mountains, and dark cavities. This ruggedness of the Moon's surface is of great use to us, by reflecting the Sun's light to all sides; for if the Moon were smooth and polished, she could never distribute the Sun's light all around. In some positions she would shew us his image no larger than a point, but with such lusture as would be hurtful to our eyes.

The Moon's surface being so uneven, many have wondered why her edge does not appear jagged, as well as the curve, bounding the light and the dark places. But if we consider, that what we call the edge of the Moon's disk is not a single line, set round with mountains, in which case it would appear irregularly indented, but a large zone, having many mountains lying behind each other from the observer's eye, we shall find that the mountains in some rows will be opposite to the valves in others, and and so fill up the inequalities, as to make her appear quite round.

The Moon being an opaque spherical body, (for her hills take off no more of her roundness, than the inequalities on the surface of an orange take off from its roundness,) we can only see that part of her enlightened half which is towards the earth. Therefore, when she is in conjunction with the Sun, her dark half is towards the earth, and she disappears; there being no light on that part to render it visible. When she comes to her first octant, or has gone over one eighth part of her orbit from her conjunction, a quarter of her enlightened side is seen towards the earth, and she appears horned. When she has gone a quarter of her orbit from between the earth and Sun; she shows us one half of her enlightened side, and then she is said to be a quarter old. When she has gone another octant, she shows us more of her enlightened side, and then she appears gibbous; and when she has gone over half her orbit, her whole enlightened side is towards the earth, and therefore she appears round: we then say it is full Moon, or the Moon is in opposition with the Sun. In her third octant, part of her dark side being towards the earth, she again appears gibbous, and is on the decrease. In her third quarter, she appears half decreased. When in her fourth octant, she again appears horned. And after having completed her course from the Sun, to the Sun again, she disappears, and we say it is new Moon. But when she is seen from the Sun, she appears always full.

The Moon's absolute motion from her change to her first quarter is so much slower than the earth's that she falls 240 thousand miles (equal to the semi-diameter of her orbit) behind the earth at her first quarter, that is, she falls back a space equal to her distance from the earth. From that time her motion is gradually accelerated to her opposition or full, and then she is come up as far as the earth, having regained what she lost in her first quarter, her motion continues accelerated so as to be just as far before the earth as she was behind it at her first quarter. But from her third quarter her motion is so retarded, that she loses as much with respect to the earth, as is equal to her distance from it, or to the semi-diameter of her orbit, and by that means the earth comes up with her, and she is again in conjunction with the sun as seen from the earth. Hence we we find that the moon's absolute motion is slower than the earths from her third quarter to her first, and swifter than the earth's from her first quarter to her third; her path being less curved than the earth's in the former case, and more in the latter. Yet it is still bent the same way towards the sun; for if we imagine the concavity of the earth's orbit to be measured by the length of a perpendicular line let down from the earth's place upon a straight line at the full of the moon, and connecting the places of the earth at the end of the moon's first and third quarters; that length will be about 640,000 miles, and the moon when new only approaching nearer to the sun by 240,000 miles than the earth. The length of the perpendicular line let down from her place at that time upon the same straight line, and which shows the concavity of that part of her path will be about 400,000 miles.

The moon's path being concave to the sun throughout, demonstrates that her gravity towards the sun at the time of her conjunction, exceeds her gravity towards the earth. And if we consider that the quantity of matter in the sun, is nearly 230 thousand times as great as the quantity of matter in the earth, and that the attraction of each body diminishes as the squares of their distances from each other increase, we shall soon find that the point of equal attraction between the earth and the sun is about 70 thousand miles nearer the earth, than the moon is at her change. It may then appear surprising that the moon does not abandon the earth when she is between it and the sun, for she is considerably more attracted by the sun, than by the earth at that time. But this difficulty vanishes when we discover that a common impulse on any system of bodies affects not their relative motions; but that they will continue to attract, impel or circulate round one another in the same manner, as if there were no such impulse. The moon is so near the earth, and both of them so far from the sun, that the attractive power of the sun may be considered as equal on both. Therefore the moon will continue to circulate round the earth in the same manner, as if the sun did not attract them at all.

OF THE PHENOMENA OF THE HARVEST MOON.

It is generally believed that the Moon rises about 50 minutes later every day, than on the preceding; but this is true only to places on the equator. In places of considerable latitude, there is a remarkable difference, especially in the time of the autumnal harvest, with which farmers were formerly better acquainted than Astronomers.

In this instance of the Harvest Moon, as in many others discoverable by Astronomy, the wisdom and beneficence of the Deity is conspicuous, who really ordered the course of the Moon, so as to bestow more or less light on all parts of the earth, as their several circumstances and seasons render it more or less serviceable.

About the equator, where there is no variety of seasons, and the weather seldom changes, except at stated times; moonlight is not necessary for gathering the produce of the ground, and there the Moon rises about 50 minutes later every day or night, than on the former.

In considerable distances from the equator, where the weather and seasons are more uncertain, the autumnal full Moons rise very soon after Sun-set, for several evenings together. At the polar circles, where the mild season is of very short duration, the autumnal full Moon rises at Sun-set from the first to the third quarter: and at the poles, where the Sun is during half the year absent, the winter full Moons shine constantly without setting from the first to the third quarter.

It is evident that all these phenomena are owing to the different angles made by the horizon, and different parts of the Moon's orbit, and that the Moon can be full but once or twice in a year, in those parts of her orbit which rise with the least angles.

The plane of the Equinox is perpendicular to the earth's axis, and therefore as the earth turns round in its diurnal revolution, all parts of the Equinox make equal parts with the horizon, both at rising and setting; so that equal portions of it always rise or set in equal times. Consequently if the Moon's motions were equible, and in the equinox at the rate of 12 degrees and 11 minutes from the Sun every day, as it is in her orbit; she would rise and set 50 minutes later every day than on the preceding; for 12 degrees, 11 minutes of the equator rise or set in 50 minutes of time in all latitudes.

The different parts ef the ecliptic, on account of its obliquity to the earth's axis, make very different angles with the horizon, as they rise or set. These parts or signs, which rise with the smallest angles, set with the greatest, and rise vice versa, In equal times, whenever this angle is least, a greater portion of the ecliptic rises, than when the angle is larger, as may be seen by elevating the pole of a common globe to any considerable latitude, and then turning it round on its own axis in the horizon.—Consequently, when the Moon is in those signs, which rise or set with the smallest angles, she rises or sets with the least difference of time, and with the greatest difference in those signs which rise or set with the greatest angles. On the parallel of London, as much of the ecliptic rises about Pisces and Aries in two hours, as the Moon goes through in six days, & therefore, when the Moon is in these signs, she differs but two hours in rising for six days together, that is about 20 miuutes later every day or night, than on the preceding at a mean rate. But in 14 days afterwards the Moon comes to Virgo and Libra, which are the opposite signs to Pisces and Aries, and then she differs almost four times as much in rising——namely: one hour and about 15 minutes later every day or night than the former, whilst she is in these signs. The annexed table shows the daily mean difference of the Moon's rising and setting

Days.	Signs.	Degrees.	Rising difference.		Setting difference.	
			h	m	h	m
1	Cancer,	13	1	5	0	50
2		26	1	10	0	43
3	Leo,	10	1	14	0	37
4		23	1	17	0	32
5	Virgo,	6	1	16	0	28
6		19	1	15	0	24
7	Libra,	2	1	15	0	20
8		15	1	15	0	18
9		28	1	15	0	17
10	Scorpio,	12	1	15	0	22
11		25	1	14	0	30
12	Sagitarius,	8	1	13	0	39
13		21	1	10	0	47
14	Capricorn,	4	1	4	0	56
15		17	0	46	1	5
16	Aquarius,	1	0	40	1	8
17		14	0	35	1	12
18		27	0	30	1	15
19	Pisces,	10	0	25	1	16
20		23	0	20	1	17
21	Aries,	7	0	17	1	16
22		20	0	17	1	15
23	Taurus,	3	0	20	1	15
24		16	0	24	1	15
25		29	0	30	1	14
26	Gemini,	13	0	40	1	13
27		26	0	56	1	7
28	Cancer,	9	1	00	1	58

on the parallel of London, for 28 days, in which time the Moon finishes her period round the ecliptic, & gets 9 degrees into the same sign from the beginning of which she set out. It appears by the table, that when the Moon is in Virgo and Libra, she rises one hour and a quarter later every day than she rose on the former, and differs only 28, 24, 20, 18, or 17 minutes in setting. But when she comes to Pisces and Aries, she is only 20 or 17 minutes later in rising.

In the time that the Moon goes round the ecliptic from any conjunction or opposition, the earth goes almost a sign forward, and therefore the Sun will seem to go as far forward in that time; (namely 27 and $\frac{1}{2}$ degrees,) so that the Moon must go 27 and $\frac{1}{2}$ degrees more than round, and as much farther as the Sun advances in that interval; which is 2 degrees and $\frac{1}{15}$ before she can be in conjunction with, or opposite to the Sun again. Hence, it is evident, that there can be but one conjunction, or opposition to the Sun and Moon, in any particular part of the ecliptic in the course of a year.

As the Moon can never be full but when she is opposite to the Sun, and the Sun is never in Virgo and Libra only in our autumnal months, it is plain that the Moon is never full in the opposite signs, Pisces and Aries, but in those two months. Therefore we can have only two full Moons in the year, which rise so near the time of setting for a week together, as above mentioned. The former of these is called the Harvest Moon, the latter the Hunter's Moon.

In northern latitudes, the autumnal full Moons are in Pisces and Aries; and the vernal full Moons in Virgo and Libra,in southern latitudes just the reverse because the seasons are contrary. But Virgo and Libra rise, at as small angles with the horizon in southern latitudes, as Pisces and Aries do in the northern; and therefore the Harvest Moons are just as regular on one side of the equator, as on the other.

As these signs which rise with the least angles, set with the greatest; the several full Moons differ as much in their times of rising every night, as the autumnal full Moons differ in their times of setting; and set with as little difference as the autumnal full Moons rise; the one, being in all cases the reverse of the other.

For the sake of plainness, the Moon has been supposed to move in the ecliptic from which the Sun never deviates. But the orbit in which the Moon really moves is different from the ecliptic, one half being elevated 5 and ½ degrees above it, and the other half, as much depressed below. The Moon's orbit therefore, intersects the ecliptic in two points diametrically opposite to each other, and these intersections are called the Moon's Nodes. The Moon can therefore never be in the ecliptic but when she is in either of her Nodes, which is at least twice in every course, and sometimes thrice. For as the Moon goes almost a whole sign more than round her orbit, from change to change, if she passes by either node about the time of her conjunction, she will pass by the other in about fourteen days after, and came round to the former node two days again before the next change. That node from which the Moon begins to ascend northwardly, or above the ecliptic in northern latitudes, is called the ascending node, and the other the descending node; because the Moon when she passes by it, descends below the ecliptic southward.

The Moon's oblique motion with regard to the ecliptic, causes some difference in the times of her rising and setting from that which has been already mentioned.

When she is northward of the ecliptic, she rises sooner, and sets later, than if she moved in the ecliptic; and when she is southward of the ecliptic, she rises later and sets sooner. This difference is variable even in the same signs, because the nodes shift backward about 19 degrees and $\frac{2}{3}$ in the ecliptic every year; and so go round it contrary to the order of signs in 18 years and 225 days.

When the ascending node is in Aries, the southern half of the Moon's orbt, makes an angle of 5 and $\frac{1}{3}$ degrees less with the horizon, than the ecliptic does, when Aries rises in northern latitudes: for this reason, the Moon rises with less difference of time, while she is in Pisces & Aries, than she would do if she kept in the ecliptic. But in 9 years and 112 days afterward,the descending node comes to Aries, and then the Moon's orbit makes an angle of 5 and $\frac{1}{3}$ degrees greater with the horizon when Aries rises, than the ecliptic does at that time; which causes the Moon to rise with greater difference of times in Pisces and Aries, than if she moved in the ecliptic.

When the ascending node is in Aries, the angle is only 9 and ⅔ degrees on the parallel of London when Aries rises. But when the descending node comes to Aries, the angle is 20 and ⅓ degrees; this occasions as great difference of the Moon's rising in the same signs every 9 years, as these would be on two parallels 10 and ⅔ degrees from each other, if the Moon's course were in the ecliptic. The following table shows how much the obliquity of the Moon's orbit, affects her rising and setting on the parallel of London, from the 12th to the 18th day of her age, supposing her to be full at the autumnal equinoxes, and then either in the ascending node, or (highest part of her orbit,) and in the descending node, (or least part of her orbit.) M signifies morning. A afternoon, and the line at the foot of the table shows a week's difference in rising and setting.

	Full in her ascending node.				Full in the highest part of her orbit				Full in her descending node				Full in the lowest part of her orbit			
moons age	Rises at		Sets at		Rises at		Sets at		Rises at		Sets at		Rises at		Sets at	
	H	M	H	M	H	M	H	M	H	M	H	M	H	M	H	M
12	5 A	15	3 M	20	4 A	30	3 M	15	4 A	32	3 M	40	5 A	16	3 M	0
13	5	32	4	25	4	50	4	45	5	15	4	20	6	0	4	15
14	5	48	5	30	5	15	6	0	5	45	5	40	6	20	5	28
15	6	5	7	0	5	42	7	20	6	15	6	56	6	45	6	32
16	6	20	8	15	6	2	8	35	6	46	8	0	7	8	7	45
17	6	36	9	12	6	26	9	45	7	18	9	15	7	30	9	15
18	6	54	10	30	7	0	10	40	8	0	10	20	7	52	10	0
diference.	1	39	7	10	2	30	7	25	3	28	6	40	2	36	7	0

This table was not computed, but only estimated, as near as could be done from a common globe, on which the Moon's orbit was delineated with a black lead pencil.

As there is a complete revolution of the nodes in 18 $\frac{1}{3}$ years, there must be a regular period of all the varieties which can happen in the rising and setting of the Moon during that time.

At the polar circles, when the Sun touches the Summer tropic, he continues twenty-four hours above the horizon; and the like number below it, when he touches the Winter tropic. For the same reason, the full Moon being as high in the ecliptic as the Summer's Sun, must therefore continue as long above the horizon: and the Summer full Moon being as low in the ecliptic as the Winter Sun, can no more rise than he does. But these are only the two full Moons which happen about the tropics, for all the others rise and set. In Summer, the full Moons are low,and their stay is short above the horizon, then the nights are short, and we have the least occasion for Moon-light. In Winter, the full Moons run high, and they stay long above the horizon when the nights are long, and we need the greatest quantity of her reflected light.

At the poles, one half of the ecliptic never sets, and the other half never rises; and therefore as the Sun is always half a year in describing one half of the ecliptic, and as long in going through the other half, it is natural to imagine that the Sun continues half a year together above the horizon of each pole in its turn, and as long below it; rising to one pole when he sets to the other, This would be exactly the case, if there were no refraction. But by the refraction of the Sun's rays, occasioned by the atmosphere, he becomes visible some days sooner, and continues some days longer in sight, than he would otherwise do: so, that he appears above the horizon of either pole, before he has got below the horizon of the other.

And as he never goes more than 23 degrees and 28 minutes below the horizon of the poles, they have very little dark night; twilight being there, as well as at all other places, till the Sun be 18 degrees below the horizon. The full Moon being always opposite to the Sun, can never be seen while the Sun is above the horizon, except when the Moon falls in the northern half of her orbit; for when any point of the ecliptic rises, the opposite point sets. Therefore, as the Sun is above the horizon of the north pole from the 20th of March, till the 23d September; it is plain that the Moon when full, being opposite to the Sun, must be below the horizon during that half of the year. But when the Sun is in the southern half of the ecliptic, he never rises to the north pole; during this half of the year, every full Moon happens in some part of the northern half of the ecliptic which never sets. Consequently, as the polar inhabitants never see the full Moon in Summer, they have her always in the Winter; before, at, and after the full, shining during 14 of our days and nights. And when the Sun is at his greatest distance below the horizon, being then in Capricorn, the Moon is at her first quarter in Aries, full in Cancer, and at her third quarter in Libra. And as the beginning of Aries is the rising point of the ecliptic, Cancer the highest, and Libra the setting point, the Moon rises at her first quarter in Aries, is most elevated above the horizon, and full in Cancer, and sets at the beginning of Libra in her third quarter, having continued visible for 14 diurnal rotations of the earth. Thus the poles are supplied one half of the Winter time with constant Moon-light, in the absence of the Sun, and only lose sight of the Moon from her third to her first quarter, while she gives but very little light, and could be but of little, and sometimes of no service to them.

Interrogations for Section Ninth.

What is understood by the Moon's Phases ?

What is discovered by observing the moon with a telescope ?

Of what use is the ruggedness to us ?

If the surface of the moon is uneven, why does it not so appear when viewed by the eye only ?

What is the moon ?

What part of the moon do we discover ?

When is she said to be in conjunction with the Sun ?

When she is in her first octant, how much of her enlightened side is visible ?

How much of her enlightened side does she show in her first quarter ?

When she has gone half around her orbit, how does she appear ?

How does she appear when viewed from the Sun ?

Are the moon's motions faster or slower than the earth's, from her change to her first quarter ?

How far does she fall behind the earth ?

From her first quarter to her full, which moves with the greatest rapidity ?

Which from the full to her third quarter ?

Which from the third quarter to the change ?

Is the gravity of the moon at any time greater towards the Sun, than towards the earth, and at what time ?

How much greater is the quantity of matter in the Sun, than in the earth ?

In what proportion does the attraction of each body diminish ?

How far from the earth is the point of equal attraction between the earth and the Sun ?

Why does not the moon leave the earth and go to the Sun ?

What is understood by the Harvest Moon ?

How many minutes later at the equator does the moon rise every day, than on the preceding ?

Is there any material difference in high northern, of southern latitudes ?

At what time in northern latitudes, does the full moon rise ?

How many days together does the moon in such cases rise at nearly the same time ?

What is the cause of this small difference ?

How far does the earth advance in her orbit, while the moon goes round the ecliptic ?

How many conjunctions and oppositions of the Sun and Moon can take place in any particular part of the ecliptic, in the course of a year ?

How many full Moons in the course of a year, that rise with so little difference near the time of Sunsetting ?

Does this singularity appear in southern latitudes, as well as in northern ?

Does the Moon's orbit lie exactly in the ecliptic ?

Does the moon's orbit intersect the ecliptic ?

What is understood by the moon's nodes ?

How many times from change to change, is the moon in her nodes ?

Which is called the ascending node ?

Which is called the descending node ?

How many degrees are they asunder ?

How much does these nodes shift in the course of a year ?

Which way do they shift ?

In what length of time do they go around the ecliptic ?

How many degrees can the Sun go below the horizon of the poles ?

How many degrees must the Sun be below the horizon before the twilight is wholly gone ?

Is the full moon in the Summer season ever seen at the north pole ?

Is it continually seen in Winter, from the first to her third quarter ?

Is it the same at the south pole ?

SECTION TENTH.

On the Ebbing and Flowing of the Sea.

THE cause of the tides was first discovered by Kepler, who thus explains it. The orb of the attracting power, (which is in the Moon,) is extended as far as the earth, and draws the waters under the torrid zone; acting upon places where it is vertical ; insensibly on confined Seas and Bays; but sensibly on the Ocean, whose beds are larger, and the waters have the liberty of reciprocation,that is of rising and falling. And in the 70th page of his lunar Astronomy he says: But the cause of the Tides of the Sea, appears to be the bodies of the Sun and Moon, drawing the waters of the Sea.

This hint being given, the immortal Sir Isaac Newton improved it, and wrote so amply on the subject as to make the theory of Tides in a manner quite his own, by discovering the cause of their rising on the side of the earth opposite to the Moon. For Kepler believed that the presence of the Moon occasioned an impulse which caused another in her absence.

It has been already mentioned, that the power of gravity diminishes as the square of the distance increases, and therefore the waters on the side of the earth, next the Moon, are more attracted than the central parts of the earth by the Moon, and the central parts are more attracted by her, than the waters on the opposite side of the earth. Therefore the distance between the earth's centre, and the water, or its surface, will be increased. If the attraction be unequal, then that body which is most strongly attracted. will move with greater rapidity, and this will increase its distance from the other body.

As this explanation of the ebbing and flowing of the Sea is deduced from the earths' constantly falling toward the Moon by the power of gravity, some may find a difficulty in conceiving how this is possible when the Moon is full, or in opposition to the Sun ; since the earth revolves about the Sun, and must continually fall towards it ; and therefore cannot fall contrary ways at the same time : or if the earth is constantly falling towards the Moon, they must come together at last. To remove this difficulty, let it be considered that it is not the centre of the earth that describes the annual orbit round the Sun, but the common centre * of gravity of the earth and Moon together; and that while the earth is moving round the Sun, it also describes a circle around that centre of gravity, going as many times around it in one revolution about the Sun, as there are lunations, or courses of the Moon around the earth; is constantly falling towards the Moon from a tangent to the circle it describes, around the said centre of gravity.

The influence of the Sun in raising the Tides, is but small in comparison of the Moon's: though the earth's diameter bears a considerable proportion to its distance from the Moon, it is next to nothing when compared to its distance from the Sun. Therefore, the difference of the Sun's attraction on the sides of the earth, under, and opposite to him, is much less than the difference of the Moon's attraction on the sides of the earth under, and opposite to her: therefore the Moon must raise the Tides much higher than they can be raised by the Sun. On this theory, (so far as it has been explained,) the Tides ought to be the highest directly under, and opposite to the Moon; that is, when the Moon is due north or south. But we find in open Seas, where the water flows freely, the Moon is gen-

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* This centre is as much nearer the earth's centre, than the Moons, as the earth is heavier, or contains a greater quantity of matter than the Moon which is about 40 times. If both bodies were suspended from it, they would hang in equilibrio. Therefore divide the Moon's distance from the earth's centre,(240,000 miles,) by 40, and the quotient, will be the distance from the centre of the earth to the centre of gravity, which is 6,000 miles, or 2,000 from the earth's surface.

erally past the north and south meridian, when it is high water. The reason is obvious, were the Moon's attraction to cease wholly when she was past the meridian, yet the motion of ascent communicated to the water before that time, would make it continue to rise for some time afterward, much more must it continue to rise, when the attraction is only diminished. A little impulse given to a moving ball, will cause it to move further than it otherwise would have done. Or, as experience shows that the weather in Summer, is warmer at 2 o'clock in the afternoon, than when the Sun is on the meridian, because of the increase made to the heat already imparted.

The Tides do not always answer to the same distance of the Moon from the meridian at the same places, but are variously affected by the action of the Sun, which brings them on sooner when the Moon is in her first and third quarters, and keeps them back later when she is in her second and fourth; because, in the one case, the Tide raised by the Sun alone, would be earlier than the Tide raised by the Moon, and in the other case later.

The Moon goes round the earth in an elliptical orbit, and therefore in every lunar month she approaches nearer to the earth than her mean distance, and recedes further from it. When she is nearest, she attracts strongest,and so raises the Tides most; the contrary happens when she is farthest, because of her weaker attraction.

When both luminaries are in the equator, and the Moon in perigee, (or at her least distance from the earth,) she raises the Tides highest of all; especially at her conjunction and opposition, both because the equatorial parts have the greatest centrifugal force from their describing the largest circle, and from the concurring actions of the Sun and Moon. At the change, the attractive forces of the Sun and Moon being united, they diminish the gravity of the waters under the Moon, and their gravity on the opposite side is diminished by means of a greater centrifugal force.—At the full, while the Moon raises the Tide under, and opposite to her; the Sun acting in the same line, raises the Tide under, and opposite to him; whence their conjoint effect is the same as at the change, and in both cases, occasion what is called, Spring Tides. But at the quarters, the Sun's action diminishes the action of the Moon on the waters, so that they rise a little under, and opposite to the Sun, and full as much under, and opposite to the Moon, making what we call Neap Tides; because the Sun and Moon then act crosswise to each other. But strictly speaking, these Tides happen not till some time after, because in this, as in other cases, the actions do not produce the greatest effect, when they are at the strongest, but sometime afterward.——The Sun being nearer the earth in Winter than in Summer, is of course, nearer to it in February and October, than in March and September, and therefore the greatest Tides happen not till some time after the autumnal equinox: and return a little before the vernal. The Sea being thus put in motion, would continue to ebb and flow for several times, though the Sun and Moon should be annihilated, or their influence cease.

When the Moon is in the equator, the Tides are equally high in both parts of the lunar day, or time of the Moons' revolving from the meridian to the meridian again; which is 24 hours and 50 minutes. But, as the Moon declines from the equator towards either pole, the Tides are alternately higher and lower at places having north or south latitude. One of the highest elevations, (which is that under the Moon,) follows her towards the pole to which she is nearest, and the other declines towards the opposite pole; each elevation describing parallels as far distant from the equator on opposite sides, as the Moon declines from it to either side, and consequently, the parallels described by these elevations of the water, are twice as many degrees from each other, as the Moon is from the equator; increasing their distance as the Moon increases her declination, till it be at the greatest; when the said parallels are at a mean state 47 degrees asunder, and on that day, the Tides are most unequal in their heights. As the Moon, returns toward the equator,the parallels described by the opposite elevations approach towards each other, until the Moon comes to the equator, and then they coincide. As the Moon declines toward the opposite pole at equal distances, each elevation describes the same parallel in the other part of the lunar day, which its opposite elevations described before. While the Moon has north declination, the greatest Tides in the northern hemisphere, are, when she is above the horizon, and the reverse when her declination is south.

Thus it appears, that as the Tides are governed by the Moon, they must turn on the axis of the Moon's orbit, which is inclined 23 degrees and 28 minutes to the earth's axis at a mean state, and therefore the poles of the Tides, must be so many degrees from the poles of the earth, or in opposite points of the polar circles, going around them in every revolution of the Moon from any meridian to the same again.

It is not, however, to be doubted, but that the quick rotation of the earth on his axis, brings the poles of the Tides nearer to the poles of the world, than they would be, if the earth were at rest, and the Moon revolved about it only once a month, otherwise the Tides would be more unequal in their heights, and times of their returns, than we find they are. But how near the earth's rotation may bring the poles of its axis, and those of the Tides together, or how far the preceding Tides may effect those that follow, so as to make them keep up nearly to the same heights and times of ebbing and flowing, is a problem more fit to be solved by observation than theory.

In open Seas, the Tides rise but to very small heights in proportion to what they do in broad Rivers, whose waters empty in the direction of the stream of Tide:— For, in channels growing narrower gradually, the water is accumulated by the opposition of the contracting bank. The Tides are so retarded in their passage through different shoals and channels, and otherwise so variously affected by striking against Capes and Headlands, that to different places, they happen at all distances of the Moon from the meridian, and consequently at all hours of the lunar day.

* Air being lighter than water, and the surface of the atmosphere nearer to the Moon, than the surface of the Sea; it cannot be doubted that the Moon raises much higher Tides in the air, than in the Sea.

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* In a register of the barometer kept for 30 years, the Professor Toaldo of Padua, added together all the heights of the mercury, when the Moon was in syzigy, when she was in quadrature, and when she was in the apogeal and perigeal points of her orbit. The apogeal exceeded the perigeal heights by 14 inches, and the heights in syzigy exceeded those in quadrature by 11 inches. The difference in these heights, is sufficiently great to show that the air is accumulated and compressed by the attraction of the Moon.

Interrogations for Section Tenth.

By whom was the cause of the TIDES first discovered ?

How does he explain it ?

Who improved the idea of Kepler ?

By what does he consider the waters to be attracted ?

Why are the waters on the side of the earth next to the Moon, more attracted than the central parts ?

Why are the central parts more attracted, than the waters on the opposite side ?

From what source is this explanation deduced ?

By what power is the earth constantly falling towards the Moon, and the Moon towards the earth ?

If this be actually the case, why do they not come together ?

Is it the centre of the earth that describes the annual orbit round the Sun ?

Where is the centre of gravity between the earth and Moon ?

How much more matter does the earth contain, than the Moon ?

What is the centre of gravity between the two bodies ?

How is it found ?

Which has the greatest influence in raising Tides, the Sun or Moon ?

Are the Tides at the highest when the Moon is due north, or south ?

What is the reason ?

Do the Tides always answer to the same distance of the Moon from the meridian at the same places ?

Does the Moon approach nearer, and recede farther from the earth in each of her revolutions ?

At what time does she attract the earth most ?

At what time does she attract it the least ?

In what position are the Sun and Moon when the highest Tides are raised ?

What are Spring-Tides ?

What are Neap-Tides ?

In what manner do the attractions of the Sun and Moon act on each other, to produce Spring-Tides ?

In what manner to produce Neap-Tides ?

Where is the moon when the Tides are equally high in both parts of the lunar day ?

What is understood by the lunar day ?

What is the length of the lunar day ?

At what time are the Tides most unequal ?

In which hemisphere are the highest Tides, when the moon has north declination ?

Which when in her south declination ?

Do the Tides rise very high in open Seas ?

Are the Tides ever retarded in their passage ?

What retards them ?

What are aerial Tides ?

How were they discovered, and by whom ?

SECTION ELEVENTH.

ASTRONOMICAL PROBLEMS.

PROBLEM I.

To convert Time into degrees, minutes, &c.

RULE.

As one hour is to 15 degrees, so is the time given to the answer.

1. How many degrees are equal to 8 hours, 20 minutes, and 30 seconds ?
2d. The Sun passes the meridian of Detroit 1 hour, 19 minutes after 12 o'clock, noon at Boston, how far are those places asunder ?

PROBLEM II.

To convert degrees, minutes, &c. into Time.

RULE.

As 15 degrees are to an hour, so are the number of degrees given to the time.

EXAMPLES.

1. The apparent distance of Venus from the Sun, can never be above 50 degrees, and when at that distance, how long does she rise before the Sun, or set after him?
2. The greatest elongation of Mercury is said to be 28 degrees, 20 minutes and 19 seconds, how long can he set after the Sun, when an evening star?

PROBLEM III.

The diurnal arc of the Sun, or of any planet being given, to find the time of the rising or setting of the Sun.

RULE.

Bring the diurnal arc into time by Problem 2d. Divide this time by two, and the quotient will be the time at which the Sun sets. Take this time from 12 hours, and the remainder will be the time at which the Sun rises.

EXAMPLES.

1. Suppose the Sun's diurnal arc be 174 degrees and thirty minutes, at what time does he rise and set. *Ans.* 5 hours 49 minutes, the time of the Sun's setting, and he rises at 6 hours and 11 minutes.
2. The diurnal arc of Venus is found to be 96 degrees and 44 minutes, at what hours does the Sun rise, and when does he set?
3. The diurnal arc of Mars, is 198 degrees, 14 minutes and 50 seconds.

The diurnal arc of Jupiter, is 201 degrees, 33 minutes and 16 seconds.

The diurnal arc of Saturn, is 196 degrees, and 14 minutes: and the diurnal arc of Herschel is 213 degrees, 41 minutes, and 58 seconds; when, according to the above mentioned numbers, does the Sun rise and set?

PROBLEM IV.

The time which the Sun, or any planet remains above the horizon being given, to find the length of his diurnal, or nocturnal arc.

RULE.

Divide the given time by two, and the quotient will be the time of the Sun's setting. Take this time from 12 hours, and the remainder will be the time of his rising. Multiply the given time by 15 degrees, and the product will give the Sun's, or planet's diurnal arc;-- this subtracted from 360 degrees, will leave the nocturnal arc.

EXAMPLES.

1. On the fourth of July, the Sun rose at 43 minutes past 5 o'clock; at what time did he set on that day, and what was the length of his diurnal arc?

2. September 7th, 1825, the Sun rose at 5 o'clock and 52 minutes, at what time did he set, and what are the dimensions of both arcs?

PROBLEM V.

To find the time which elapses between two conjunctions, or two oppositions, or between one conjunction, and one opposition of any two planets.

RULE.

Find the difference between the given daily motions of the two given planets, as given in the following table of the daily motions, then say, as the difference of their daily motions, is to one day, so is 360 degrees, to the difference in the times of the two conjunctions, or oppositions required. But for one conjunction, and one opposition, or, for a superior and an inferior conjunction; say as the difference of their daily motions is to one day, so is 180 degrees to the time, which elapses between a conjunction, and an opposition of the two given planets.

TABLE.

			D.
Mercury's daily motion is			4,0928 degrees.
Venus',	do.	do.	1,6021
The earth's,	do.	do.	0,9856
Mars',	do.	do.	0,5240
Jupiter's,	do.	do.	0,0831
Saturn's,	do.	do.	0,0335
Herschel's,	do.	do.	0,0118

EXAMPLES.

1. How many days elapse between a conjunction, and an opposition of Mercury and Venus.

Thus Mercury's daily motion, 4,0928 degrees
Less the daily motion of Venus, 1,6021=2,4907
Degrees,then as 2,4907 *d*: 1 *day* : : 180 *d*: 72,25 days, the time required.

2. How many days is Venus a morning and an evening star, alternately to the earth ?

3. How many days is Jupiter a morning and evening star, alternately to the earth ?

4. How many days is Mercury east, and how many west of the Sun to us ?

PROBLEM VI.

The heliocentric longitude of any two planets being given, to find when they will be in heliocentric conjunction.

RULE.

Subtract the given longitude of the planet nearest the Sun, from that of the planet farthest from him, if practicable, but if not, add to the latter 360 degrees, and then subtract, say, as the difference of the daily motions of the given planets is to one day, so is the difference of their longitudes, to the time when the given planets will be in conjunction.

EXAMPLES.

1. At what time were Mars and Venus in conjunction, after the first of January, 1823.

Venus' daily motion is 1,6021—0,5240=1,0781—Mars' longitude for January 1st. 1823, was 311 degrees and 41 minutes: less by 285 degrees, 16 minutes, the longitude of Venus at the same time=26 degrees and 25 minutes. Then as 1,0781 : 1 day : : 26 *d.* 25 *m.* =24,5, or January 25th, 1823.

TABLE.

	Degrees.
The Sun's geocentric longitude for January 1st. 1823, was,	280—29 *min.*
The heliocentric longitude of Mercury, January 1st. 1823, was	277—25
That of Venus, was	285—16
The Earth's,	100—20
That of Mars,	311—41
Jupiter's,	64—51
Saturn's,	38—56
Herschel's,	277—30

On what day of the year, 1823, was Venus in conjunction with the earth ?

3. When was Jupiter in conjunction with the earth in the year 1824 ?

4. When were Venus and Jupiter in conjunction, in 1825 ?

5. On what day in the year 1832, did Jupiter set ; at the moment the Sun arose ?

PROBLEM VII.

When the heliocentric longitude of any planet, for any given day is known, to find it for any required day.

RULE.

Find the number of days between the given, and required day : then as one day is to the given planet's daily motion, so are the days so found, to the distance which the planet has revolved during that time. Add this distance to the planet's known longitude, and the sum, if less than 360 degrees, will be the longitude for the required day, but if more than 360 degrees. then subtract 360 degrees from it, and the remainder will be the true longitude,

EXAMPLES,

1. On the first of January, 1823, the heliocentric longitude of Venus was 285 degrees, 16 min. ; what was it on the 4th of July, in the same year ? *Ans.* 220 degrees and three minutes.
2. On the first of January, 1823, the earth's longitude was 100 degrees and 20 minutes ; what was its longitude on the 4th of July, 1825 ?

PROBLEM VIII

To determine whether Venus or Jupiter will be the morning or evening star on any given day.

RULE.

Find the longitude of Venus and the longitude of the earth for the given day. If the difference in longitude, counting from the earth's place eastward, be less than 180 degrees, Venus will be east of the Sun, and consequently evening star : but if that difference be greater than 180 degrees, she will be west of the Sun, and therefore morning star.

EXAMPLES.

On the 4th of July, 1823, was Venus a morning or an evening star ?

The longitude of Venus on the given day, will be found by Problem 7th, to be 220 degrees and 3 minutes, and the earth's longitude, for the same day by the same Problem, 281 degrees and 41 minutes ; the difference=61 degrees and 38 minutes; this difference being less than 180 degrees, shows that Venus is east of the Sun, and consequently an evening star.

Did Jupiter rise before, or after the Sun, July 4th, 1832 ?

How many days in succession, can Venus be a morning, or an evening star ?

How many days in succession, can Jupiter be a morning or an evening star ?

PROBLEM IX.

To determine the day on which any particular planet shall have a given longitude.

RULE.

Subtract the longitude of the given planet found in the preceding table,from the given longitude,if practicable ; but if the longitude of the planet found in the Table, be greater than the given longitude, increase the latter by 360 degrees, and then subtract; divide the remainder by the planet's daily motion, as recorded in the Table, and the quotient will show the number of days from the first of January, when the planet will have the given longitude.

EXAMPLES.

1. On what day of the year 1823, did Venus have 220 degrees of heliocentric longitude ? *Answer*—fourth of July.
2. On what days in the year 1825, did each of the planets enter Virgo ?

PROBLEM X.

To find whether Venus or Mercury will cross the Sun's disk in any given year.

RULE.

Find by Problem 9th when Venus will pass her node. Find the earth's heliocentric longitude for that day, and if it equals the longitude of Venus' node, there will be a transit of Venus, and in no other case. The same may be said of the planet Mercury.

EXAMPLES.

Were there a transit of Venus in the year 1824, or not ?

The longitude of the ascending node of Venus, is 75 degrees and 8 minutes, which she passed on the 26th of June. The earth's longitude on that day, was 274 degrees and 44 minutes. The longitude of the descending node of Venus, was 258 degrees and 8 minutes, which she passed on the 5th of March. The earth's longitude on that day, was 164 degrees and 55 minutes, consequently there was no transit of Venus in 1824.

PROBLEM XI.

To find when any two given planets shall have a given heliocentric aspect, taking their longitudes as stated in the Table for 1823.

RULE.

Add the degrees in the aspect given to the heliocentric longitude of either given planet. Find the difference between that sum and the heliocentric longitude of the other given planet : Then say, as the difference in the daily motions of the two given planets, is to one day,so is the difference in their longitude found as above to the answer required.

EXAMPLES.

At what time in the year 1824, did the earth and Venus have a trine aspect ?

The longitude of the earth for January 1st. for that year, was 100 degrees and 6 minutes, to the earth's longitude, add 120 degrees, (the given aspect,) and the sum is 220 degrees and 6 minutes.

The longitude of Venus on the first day of January, 1824, was 150 degrees and two minutes ; the difference was 70 degrees and 4 minutes ; Then 1,6021 degrees—,9856=,6165 difference of daily motion. Then ,6165 : 1 day : : 70 d. 4 minutes : 113 days, or the 22d. of April.

2. On what day were the earth and Jupiter in conjunction in the year 1826 ?
3. When in 1835, will the earth and Venus be in conjunction ?

☞ **NOTE.**—The preceding PROBLEMS would be correct, if the Planets moved in perfect circular orbits, which however is not the fact, yet they approach so near to circles, that deductions founded upon their figure as circles, are sufficiently accurate for ordinary calculations.

SECTION TWELFTH.

ON ECLIPSES.

In the Solar System, the Sun is the great fountain of Light, and every planet and satellite is illuminated by him, receive the distribution of his rays, and are irradiated by his beams. The rays of light are seen in direct lines, and consequently are frequently intercepted by the dark and opaque body of the Moon, passing directly between the earth and the Sun; and hiding a portion, or the whole of his disk from the view of those parts of the earth where the penumbra, or the shadow of the Moon happens to fall. This is called an Eclipse of the Sun.

It is only at the time of new Moon, that an Eclipse of this kind can possibly take place, and then only when the Sun is within seventeen degrees of either the ascending or descending nodes; for if his distance at the time of new Moon be greater than seventeen degrees from either node, no part of the Moon's shadow will touch the earth, and consequently there will be no Eclipse.

The orbit in which the Moon really moves, is different from the ecliptic, one half being elevated five and one-third degrees above it, and the other half as much depressed below. The Moon's orbit therefore intersects the ecliptic in two points diametrically opposite to each other, and these intersections are called the Moon's nodes. The Moon, therefore can never be in the ecliptic, but when she is in either of her nodes; which is at least twice in every lunation, or course from change to change, and sometimes thrice. That node from which the Moon begins to ascend northward, or above the ecliptic in northern latitudes is called the ascending node; and the other the descending node; because the Moon when she passes by it descends below the ECLIPTIC southward. The ECLIPTIC is the great circle which the earth describes in its annual revolution around the Sun, and is divided into twelve equal parts, of thirty degrees each called signs. Six of these, namely, Aries, Taurus, Gemini, Cancer, Leo and Virgo are north; and the other six, to wit, Libra, Scorpio, Sagitarius, Capricornus, Aquarius and Pisces, south of the equotor.*

When the earth comes between the Sun and Moon, the Moon passes through the earth's shadow, and having no light of her own, she suffers a real Eclipse; the rays of the Sun being intercepted by the earth. This can only happen at the time of full Moon; and, when the Sun is within twelve degrees of the Moon's ascending or descending nodes. Should the Sun's distance from the node exceed twelve degrees, the shadow of the earth would no where touch the surface of the Moon, and consequently she could not suffer an Eclipse.

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* The Equator is an imaginary circle passing round the earth from east to west, dividing it into two equal parts, called Hemispheres.

When the Sun is Eclipsed to us, the inhabitants of the Moon on the side next the earth, see her shadow like a dark spot travelling over the earth about twice as fast as its equatorial parts move, and the same way.

When the earth passes between the Sun and Moon, the Sun appears in every part of the Moon where the earth's shadow falls totally Eclipsed; and the duration is as long as she remains in the earth's shadow.

If the earth and Sun were of equal sizes, the shadow of the earth would be infinitely extended, and wholly of the same breadth, and the planet Mars when in either of her nodes, and in opposition to the Sun, (although forty-two millions of miles from the earth,) would be Eclipsed by the shadow. If the earth were larger than the Sun, her shadow would be sufficient to Eclipse the larger planets, Jupiter and Saturn with all their satellites, when they were opposite to him; but the shadow of the earth terminates in a point long before it reaches any of the primary planets. It is therefore evident, that the earth is much less than the Sun, or its shadow could not end in a point at so short a distance.

If the Sun and Moon were of equal sizes, she would cast a shadow on the earth's surface of more than two thousand miles in breadth, even if it fell directly against its centre. But the shadow of the Moon is seldom more than one hundred and fifty miles in breadth at the earth, unless in total Eclipses of the Sun, her shadow strikes on the earth in a very oblique direction.

In annular Eclipses, the Moon's shadow terminates in a point at some distance before it reaches the earth; and consequently the Moon is mnch less than the Sun. If the Moon were actually thrice its present size, it would still in many instances, be totally Eclipsed. A sufficient proof of this, is given by her long continuance in the earth's shadow, during any of her total Eclipses. Therefore the diameter of the earth is more than three times the diameter of the Moon.

Though all opaque bodies, on which the Sun shines, have their shadows; yet such is the magnitude of the Sun, and the distances of the planets, that the primaries can never Eclipse each other. A primary can only Eclipse its secondary, or be Eclipsed by it, and never by those except when they are in opposition or conjunction with the Sun, as before stated. The primary planets are very seldom in such positions, but the Sun and Moon are, in every month.

If the Moon's orbit were coincident with the plane of the ecliptic, in which the earth wheels its stated courses, the Moon's shadow would fall on the earth at every change, and the Sun be eclipsed to every part of the earth where the penumbra happened to fall. In the same manner, the Moon would have to travel through the middle of the earth's shadow, and be totally Eclipsed at every full. The duration of total darkness in every instance, exceeding an hour and a half.

A question like the following naturally arises :— Why is it that the Sun is not Eclipsed at every change, if the Moon actually passes between the Sun and the earth. And why is not the Moon Eclipsed at every full, if the earth passes between the Sun and Moon in every month ?

One half of the Moon's orbit, is elevated 5 degrees and twenty minutes above the ecliptic, and the other half is as much depressed below it ; and, as before has been observed, the Moon's orbit intersects the ecliptic, in two opposite points, called the MOON'S NODES.

When these points are in a right line with the centre of the Sun at new or full Moon, the Sun, Moon,and earth are all in a right line ; and if the Moon be then new; her shadow falls upon the earth, but if she be full, the earth's shadow falls upon her. When the Sun and Moon are more than 17 deg's. from either of the nodes at the time of conjunction,the moon is generally too high or too low in her orbit to cast any part of her shadow on the surface of the earth. And when the Sun is more than 12 degrees from either of the nodes at the time of full Moon, the Moon is generally either two high or too low to pass through any part of the earth's shadow ; therefore in both these cases there can be no Eclipse.

This howevever admits of some variation, for in apogeal Eclipses, the solar limit is only sixteen degrees and thirty minutes, and in perigeal it is eighteen degrees and twenty minutes. When the full Moon is in her apogee, * she will be Eclipsed, if she be within 16 degrees and thirty minutes of the node; and when in her perigee, if within twelve degrees and two minutes.

The moon's orbit contains 360 deg's. of which the limits of seventeen degrees at a mean rate for Solar Eclipses, & twelve for lunar are only small portions, and the Sun generally passes by the nodes only twice in a year, and consequently impossible that Eclipses should happen in every month. If the line of the nodes, like the axis of the earth, were carried parallel to itself around the Sun, there would be exactly half a year between the conjunctions of the Sun and nodes. But the nodes shift backward, or contrary to the earth's annual motion, nineteen degrees and twenty minutes every year; and therefore the same node comes round to the Sun nineteen days sooner every year, than in the one preceeding. 173 days, therefore, after the ascending node has passed by the Sun, the descending node also passes by him. In whatever season of the year the luminaries are Eclipsed, in 173 days after, we may expect Eclipses about the opposite node. The nodes shift through all the signs and degrees of the ecliptic in 18 years and 225 days, in which time there would always be a regular periodical return of Eclipses, if any number of lunations were completed without a

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* The fartherest point of each orbit from the earth's centre is called the apogee, and the nearest point is called the perigee. These points are directly opposite each other, and consequently exactly six signs asunder.

fraction. But this never happens, for if both the Sun and Moon should start from a line of conjunction with either of the nodes in any point of the ecliptic, the Sun would perform 18 annual revolutions and 222 degrees of the 19th, and the Moon 230 lunations, and 85 degrees of another by the time the node came around to the same point of the ecliptic again.

The Sun would then be 138 degrees from the node, and the Moon 85 degrees from the Sun. In 223 mean lunations after the Sun, Moon and node, have been in a line of conjunction, they return so nearly to the same state again, that the same node which was in conjunction with the Sun and Moon at the commencement of these lunations, will be within 28 minutes, and 12 seconds of a degree of a line of conjunction with the Sun and Moon again, when the last of these lunations is completed. In that time, there will be a regular period of Eclipses, or rather a periodical return of the same eclipse for many ages. In this period, (which was first discovered by the Chaldeans,) there are 18 Julian years, 11 days, 7 hours, 43 minutes, and 21 seconds, when the 29th day of February in leap years, is four times included ; but one day less when included 5 times. Consequently, if to the mean time of any Eclipse, whether of the Sun or Moon, the above named time be added, you will have the mean time of its periodical return. But the falling back of the line of conjunctions, or oppositions of the Sun and Moon, namely, 28 minutes, 12 seconds, with respect to the line of the nodes in every period, will wear it out in process of time, so that the shadow will not again touch the earth or Moon, during the space of 12,492 years. Those Eclipses of the Sun which happen about the ascending node, and begin to come in at the north pole of the earth, will continue at each periodical return to advance southwardly, until they leave the earth at the south pole; and the contrary with those that happen about the descending node, and come in at the south pole. From the time that an Eclipse of the Sun first touches the earth, until it completes its periodical returns, and leaves the same, there will be 77 periods equal to 1388 years. The same Eclipse cannot then again touch this earth, in a less space than 12492 years as above stated.

If the motions of the Sun, Moon, and nodes were the same in every part of their orbits, we should need nothing more than what has been said to find the exact time of all Eclipses; but as this is not the case, we are under the necessity of forming Tables so constructed, that the mean time can be reduced to the true. By the following example, it will be found, that by the true motions of the Sun, Moon and nodes, the Eclipse calculated, leaves the earth five periods sooner than it would have done, by mean equable motions. To exemplify this matter more fully, I will take the Eclipse of the Sun, which happened in the year 1764, March 21st. Old Style, (or April 1st. in the new,) according to its mean revolutions, and also according to its true equated time.

The shadow, or penumbra of the Moon, fell in open space at each return, without touching the earth ever since the creation, until the year of our Lord, 1295; then on the 14th day of June, at 52 minutes, and 59 seconds in the morning, Old Style, the Moon's shadow touched the earth at the north pole. In each succeeding period since that time, the Sun has come 28 minutes and 12 seconds nearer the same node, and the Moon's shadow has gone more southwardly. In the year 1962, on the 18th of July, Old Style, (or 31st. in the new,) at 10 hours. 36 minutes, 21 seconds in the afternoon, the same Eclipse will have returned 38 times. The Sun will then be only 24 minutes and 45 seconds from the ascending node, and the centre of the Moon's shadow will fall a little north of the equator.—At the end of the next following period, in the year 1980, July 29th, Old Style, (or August 11th in the new,) at 6 hours, 19 minutes and 41 seconds in the morning, the Sun will have receded back three minutes and twenty-seven seconds from the ascending node; the Moon will then have a small degree of south latitude, and consequently cast her shadow a little south of the equator. After this, at every following period, the Sun will be 28 minutes and 12 seconds further back from the ascending node than at the preceding, and the Moon's shadow will continue at each succeeding period to approach nearer the south pole, until September 13, Old Style, (or October 1st. in the new,) at 11 hours, 46 minutes and 22 seconds in the morning, in the year 2665, when the Eclipse will have completed its 77th periodical return, and the shadow of the Moon leaves the earth at the south pole to return no more, until the lapse of 12492 years. But on account of the true, (or unequable) motions of the Sun, Moon, & nodes, the first coming in of this Eclipse at the north pole of the earth, was on the 24th of June, 1313, at 3 hours, 57 minutes, and 3 seconds in the afternoon, and it will finally leave the earth at the south pole on the 18th day of August, (according to New Style,) in the year 2593, at 10 hours, 25 minutes and 31 seconds afternoon, at the 72d. period. So that the true motions do not only alter the true times from the mean, but they also cut off five periods from those of the mean returns of this Eclipse.

In any year, the number of Eclipses of both luminaries cannot be less than two, nor more than seven; the most usual number is four, and it is very rare to have more than six. The Eclipses of the Sun are more frequent than those of the Moon, because the Sun's ecliptic limits are greater than those of the Moon's.—(The proportions being as 17 is to 12,) yet we have more visible Eclipses of the Moon, than of the Sun; because Eclipses of the Moon are seen from all parts of that hemisphere of the earth which is next her; and are equally great to each of those parts; but Eclipses of the Sun are only visible to that small portion of the hemisphere next him, whereon the Moon's shadow happens to fall.

The Moon's orbit being elliptical, and the earth in one of its focuses; she is once at her least distance from the earth, and once at her greatest in every lunation or revolution around the earth. When the Moon changes at her least distance from the earth, and so near the node that her dark shadow falls on the earth; she appears sufficiently large to cover the whole disk of the Sun from that part on which her shadow falls, and the Sun appears totally eclipsed for the space of four minutes.

But when she changes at her greatest distance from the earth, and so near the node that her dark shadow is directed towards the earth, her diameter subtends a less angle than the Sun's, and therefore cannot hide the whole disk from any part of the earth, nor does her shadow reach it at that time; and to the place over which the point of her shadow hangs, the Eclipse is annular, and the edge of the Sun appears like a luminous ring around the whole body of the Moon. When the change happens within 17 degrees of the node, and the Moon at her mean distance from the earth, the point of her shadow just touches the earth, and the Sun is totally eclipsed to that small spot on which the Moon's shadow falls; but the duration of total darkness is not of a moment's continuance. The Moon's apparent diameter when largest, exceeds the Sun's when least, according to the calculations of modern Astronomers, two minutes and five seconds, the duration of total darkness, therefore may at such time continue four minutes and six seconds; casting a shadow on the earth's surface of 180 miles broad. When the Moon changes exactly in the node, the penumbra is circular on the earth at the middle of the general Eclipse, because at that time it falls perpendicularly on the earth's surface; but in every other moment, it falls obliquely, and therefore will be elliptical, and the more so, as the time is longer after the middle of the general Eclipse; and then much greater portions of the earth are involved in the penumbra.

When the penumbra first touches the earth the general Eclipse begins, and it ends when it leaves the earth: from the beginning to the end, the sun appears Eclipsed in some part of the earth or other. When the penumbra touches any place, the Eclipse begins at that place, and ends, when the penumbra leaves it. When the moon changes exactly in the node the penumbra goes over the centre of the earth as seen from the moon, and consequently by describing the longest line possible on the earth continues the longest upon it; namely at a mean rate five hours and fifty minutes: more, if the moon be at her greatest distance from the earth, because she then moves slowest, and less if she be at her nearest approach, because of her accelerated motion.

The moon changes at all hours, and as often in one node as in the other, and at all distances from them both, at different times as it happens; the variety of phases of Eclipses are therefore almost innumerable, even at the same places, considering also how variously the same places are situated on the enlightened disk of the earth with respect to the motion of the penumbra, at the different hours when Eclipses happen.

When the Moon changes 17 degrees short of her descending node, the penumbra just touches the northern part of the earth's disk near the north pole, and as seen from that place, the Moon appears to touch the Sun, but hides no part of him from sight. Had the change been as far short of the ascending node, the penumbra would have touched the southern part of the disk near the south pole. When the Moon changes 12 degrees short of the descending node, more than a third part of the penumbra, falls on the northern parts of the earth at the middle of the general Eclipse. Had she changed as far past the same node, as much of the other side of the penumbra would have fallen on the southern parts of the earth, all the rest in open space.

When the Moon changes 6 degrees from the node, almost the whole penumbra falls on the earth at the the middle of the general Eclipse.

The further the Moon changes from either node within 17 degrees of it, the shorter is the penumbra's continuance on the earth; because it goes over a less portion of the disk. The nearer the penumbra's centre is to the equator at the middle of the general Eclipse, the longer is its duration at places where it is central; because the nearer that any place is to the equator, the greater is the circle it describes by the earth's motion on its axis, and the place moving quick keeps longer in the penumbra, whose motion is the same way with that of the place, though faster as has been mentioned. That Eclipses of the Moon can never happen only at the time of full, and the reason why she is not eclipsed at every full, has already been mentioned.

The Moon when totally eclipsed, (though a dark opaque body, and shines only by reflection,) is not invisible, if she be above the horizon, and the sky clear; but generally appears of a dusky color which some have thought to be her native light. But the true cause of her being visible, is the scattered beams of the Sun, bent into the earth's shadow by going through the atmosphere, which being more dense near the earth, than at considerable heights above it, refracts, or bends the rays of the Sun more inward the nearer they are passing by the earth's surface, than those rays which go through higher parts of the atmosphere where it is less dense; according to its height, until it be so thin, or rare as to lose its refractive power.

When the Moon goes through the centre of the earth's shadow, she is directly opposite to the Sun, yet the Moon has been often seen totally eclipsed in the horizon, when the Sun was also visible in the opposite part of it; for the horizontal refraction being almost 34 minutes of a degree, and the diameter of the Sun and Moon being each at a mean state but 32 minutes, the refraction causes both luminaries to appear above the horizon, when they are actually below it. When the Moon is full at 12 degrees from either node, she just touches the earth's shadow, but does not enter into it. When she is full at 6 degrees from either node, she is totally, but not centrally immersed in the earth's shadow, she takes the longest line possible, which is the diameter through it, and such an Eclipse, (being both total, and central,) is of the longest duration, namely, three hours, 57 minutes and 6 seconds from the beginning to the end, if the Moon be at her greatest distance from the earth ; and 3 hours, 37 minutes and 26 seconds, if she be at her least distance.

The reason of this difference is, that when the Moon is farthest from the earth, her motions are retarded, but when nearest to the earth, her motions are accelerated.

Interrogotions for Section Twelfth.

Are the rays of light proceeding from the Sun, frequently intercepted ?

By what are they intercepted ?

What is understood by the penumbra ?

What is an Eclipse of the Sun ?

At what stage of the Moon does an Eclipse of the Sun happen ?

How near to either of the nodes must the Sun be to suffer an Eclipse ?

Does the Moon's orbit differ from the ecliptic ?

What is the ecliptic ?

What are the Moon's nodes ?

Why cannot the Sun be eclipsed unless he be within 17 degrees of the node ?

How often is the Moon in the ecliptic ?

Which is called the ascending node ?

Which is called the descending node ?

What is an Eclipse of the Moon ?

At what stage of the Moon does this happen ?

How near must the Sun be to either of the nodes, so that the Moon can suffer an Eclipse ?

What causes it ?

Should the same distance from either node at the time of full Moon exceed twelve degrees, could the shadow of the earth touch the surface of the Moon?

As the Moon passes between the Sun and the earth at every new Moon, why is not the Sun eclipsed at every new Moon?

Why is not the Moon eclipsed at every full?

What is the farthest point of each orbit from the earth's centre called?

What the nearest point?

How many times a year does the Sun generally pass by the nodes?

In what time do the nodes pass through all the signs of the ecliptic?

How many lunations after the Sun, Moon and nodes have been in conjunction, before they return nearly to the same state again?

What is a periodical return of an Eclipse?

Are the motions of the Sun, Moon and nodes the same in every part of their orbits?

How can the mean time of these conjunctions be reduced to the true?

How many are the greatest number of Eclipses that can possibly happen in one year?

How many the least?

What the most usual number?

Which is the most ſrequent, those of the Sun or Moon?

What is the reason?

Are there more visible Eclipses of the Moon than of the Sun?

What is the reason?

What is a total Eclipse of the Sun?

How long can the Moon hide the whole face of the Sun from our view?

In what part of her orbit must the Moon be to cause a total Eclipse?

What is an annular Eclipse?

How many miles in diameter would the shadow of the Moon be on the earth, in an Eclipse when total darkness continues four minutes?

When the Moon changes exactly in the node, what is the form of the shadow, and where does it strike the earth?

When does an Eclipse begin?

When does it end?

When does it begin and end at any particular place?

When the Moon changes 17 degrees short of her descending node, where will her shadow touch the earth?

If as far short of her ascending node, where on the earth will her shadow fall?

Why in total Eclipses of the Moon is she not invisible, if she be a dark opaque body?

Is it possible for the Moon to be visibly eclipsed while the Sun is in sight?

When the Moon is full, within six degrees of either node, will she be totally eclipsed?

When she passes by the node in the earth's shadow, how much of the Moon will be eclipsed?

What is the longest time that the Moon can suffer an Eclipse?

What the shortest if she be at her least distance?
Why is this difference?

What is the time of the longest duration of an Eclipse of the Sun?

What the shortest, if the Eclipse be central?

SECTION THIRTEENTH.

SHOWING THE PRINCIPLES ON WHICH THE FOLLOWING
ASTRONOMICAL TABLES ARE CONSTRUCTED,
AND THE METHOD OF CALCULATING
THE TIMES OF NEW & FULL
MOONS & ECLIPSES
BY THEM.

The nearer that any object is to the eye of an observer, the greater is the angle under which it appears.—The farther from the eye, the less it appears.

The diameters of the Sun and Moon subtend different angles at different times. And at equal intervals of time, these angles are once at the greatest, and once at the least, in somewhat more than a complete revolution of the luminary through the ecliptic from any given fixed star, to the same star again. This proves that the Sun and Moon are constantly changing their distances from the earth and that they are once at their greatest distance, and once at their least, in a little more than a complete revolution.

The gradual differences of these angles are not what they would be, if the luminaries moved in circular orbits, the earth being supposed to be placed at some distance from the centre.

But they agree perfectly with elliptical orbits, supposing the lunar focus of each orbit to be at the centre of the earth.

The farthest point of each orbit from the earth's centre, is called the apogee; & the nearest point the perigee. These points are directly opposite each other.

Astronomers divide each orbit into 12 equal parts, called signs; and each sign into 30 equal parts called degrees; each degree into sixty equal parts, called minutes,and each minute into 60 equal parts, called seconds. The distance,therefore, of the Sun or Moon from any point of its orbit, is reckoned in Signs, Degrees, Minutes and Seconds. The distance here meant, is that through which the luminary has moved from any given point,(not the space it falls short thereof,) in coming round again,be it ever so little.

The distance of the Sun or Moon from its apogee at any given time, is called its mean anomaly, so that in the apogee, the anomaly is nothing, in the perigee, it is six signs.

The motions of the Sun and Moon are observed to be continually accelerated from the apogee to the perigee; and as gradually retarded from the perigee to the apogee; being slowest of all when the mean anomaly is nothing, and swiftest when it is six signs.

When the luminary is in its apogee or perigee, its place is the same as it would be if its motions were equable in all parts of its orbit. The supposed equable motions are called mean, the unequable are justly called the true.

The mean place of the Sun or Moon is always forwarder than the true, whilst the luminary is moving from its apogee to its perigee; and the true place is always forwarder than the mean, whilst the luminary is moving from its perigee to its apogee. In the former case, the anomaly is always less than six signs, in the latter more.

It has been discovered by a long series of observations, that the Sun goes through the ecliptic, from the vernal equinox to the same again, in 365 days, 5 hours, 48m. and 54s. And from the first star of Aries, to the same star again, in 365 days, 6 hours, 9 minutes, and 24 seconds. And from his apogee to the same again in 365 days, 6 hours, and 14 minutes. The first of these, is called the Solar year; the second the sydereal, and the third the anamolistic year. The solar year is 20 minutes and 29 seconds shorter than the sydereal; and the sydereal year is 4 minutes and 36 seconds shorter than the anamolistic. Hence it appears, that the equinoxial point, or intersection of the ecliptic and equator at the beginning of Aries, goes backward, with respect to the fixed stars, and that the Sun's apogee goes forward.

The yearly motion of the earth's or Sun's apogee, is found to be one minute and six seconds, which being subtracted from the Sun's yearly motion, in longitude, the remainder is the Sun's mean anomaly.

It is also observed, that the Moon goes through her orbit from any given fixed star to the same again, in 27 days, 7 hours, 43 minutes, and 4 seconds, at a mean rate; from her apogee to her apogee again in 27 days, 13 hours, 18 minutes, and 43 seconds: and from the Sun to the Sun again in 29 days, 12 hours, 44 minutes, and 3 and $\frac{1}{20}$ seconds. This confirms the idea that the Moon's apogee moves forward in the ecliptic, and that at a much greater rate than the Sun's apogee; since the Moon is 5 hours, 55 minutes, and 39 seconds longer in revolving from her apogee to her apogee again, than from any star to the same again.

The Moon's orbit crosses the ecliptic in two opposite points, which are called her nodes, and it is observed that she revolves sooner from any node to the same node again, than from any star to the same star again, by 2 hours, 38 minutes and 27 seconds; which shows that her nodes move backward, or contrary to the order of signs in the ecliptic.

To find the Moon's mean motion in a common year of 365 days, the proportion is

	D	H	M	S
As the Moon's period,	27	7	43	5
Is to her whole orbit, or	360 degrees,			
So is a common year of	365 days,			

To 13 revolutions and 4*s.*—9*d.*—23 minutes, 5 seconds. The thirteen revolutions are rejected, and the remainder is taken for the Moon's motion in 365 days.

To calculate the Moon's mean anomaly:

The Moon's apogee moves once round her whole orbit in 8 years, 309 days, 8 hours, and 20 minutes, or, (adding two days for leap years,) in 3231 days, eight hours and 20 minutes. Then,

As 3231d.—8h.—20
Is to the whole circle, or 360 degrees,
So is a common year of 365 days,
To the motion of the Moon's apogee in one year= 40 degrees, 39 minutes, and 50 seconds.

From the Moon's mean motion in longitude during one year,
S D M S
4 9 23 5 Subtract
the motion of her apogee, 1 10 39 50 for the same
time, and there remains, 2–28—43–15 the Moon's
mean anomaly in one year.

To find the mean motion of the Moon's node:

The Moon's node moves backward round her whole orbit in 18 years, 224 days, 5 hours, therefore for its motion in 365 days,

As 18 years, 224 days, 5 hours
Is to the whole circle or 360 degrees,
So is the year of 365 days
To the motion of the Moon's node in 365 days=19 degrees, 19 minutes and 43 seconds.

To find the mean motion of the Moon from the Sun.

The Moon's mean motion in a common year of 365 days, is 4 signs, 9 degrees, 23 minutes and 5 seconds over and above 13 revolutions, and the Sun's apparent mean motion in the same time is 11 signs, 29 degrees, 45 minutes and 40 seconds. Then from the Moon's mean motion for one year, subtract the mean motion of the Sun for the same time, and the remainder will be the mean motion of the Moon from the Sun in one year=4 signs, 9 degrees, 37 minutes and 25 seconds.

The time, in which the Moon revolves from the Sun to the Sun again, (or from change to change,) is called a lunation, which would always consist of 29 days, 12 hours, 44 minutes, 3 seconds, 2 thirds and 58 fourths, if the motions of the Sun and Moon were always equable. Hence 12 mean lunations contain 354 days, 8 hours, 48 minutes, 36 seconds, 35 thirds, and 40 fourths; which is 10 days, 21 hours, 11 minutes, 23 seconds, 24 thirds, and 20 fourths less than the length of a common Julian year, consisting of 365 days and 6 hours; and 13 mean lunations contains 383 days, 21 hours, 32 minutes, 39 seconds, 38 thirds, and 38 fourths, which exceeds the length of a common Julian year by 18 days, 15 hours, 32 minutes, 39 seconds, 38 thirds, and 38 fourths.

The mean time of new Moon being found for any given year and month, as, suppose for March, 1700, Old Style; if this new Moon happens later than the 11th of March, then 12 mean lunations added to the time of this mean new Moon, will give the time of the mean new Moon in March, 1701, after having thrown off 365 days. But, when the mean new Moon happens before the 11th of March, we must add 13 mean lunations, to have the mean time of mean new Moon in March, following, always taking care to subtract 365 days in common years, and in leap years, 366, from the sum of this addition.

Thus in the year 1700, Old Style, the time of mean new Moon in March, was the 8th day, at 16 hours, 11 minutes, and 25 seconds past four, in the morning of the 9th day, (according to common reckoning.) To this we must add 13 mean lunations, from which subtract 365 days, because the year 1701 is a common year, and there will remain 27 days, 13 hours, 44 minutes, 4 seconds, 38 thirds and 38 fourths, for the time of mean new Moon in March, in the year 1701.

By carrying on this addition and subtraction, until the year 1703, we find the time of new Moon in March that year, to be on the 6th day, at 7 hours, 21 minutes, 17 seconds, 49 thirds, and 46 fourths, past noon; to which add 13 mean lunations, and subtract 366 days, (the year 1704 being leap year,) and there will remain 24 days, 4 hours, 53 minutes, 57 seconds, 28 thirds and 20 fourths, for the time of mean new Moon in March, 1704. In this manner, was the first of the following Tables constructed to seconds, thirds, and fourths, and then written to the nearest seconds.

The reason why we chose to begin the year with March, was to avoid the inconvenience of adding a day to the tabular time in leap years, after the month of Feb'y. or subtracting a day therefrom, in January,or February in those years; to which all tables of this kind are subject, (which begin the year with January,) in calculating the times of new or full Moon.

The mean anomalies of the Sun and Moon, and the Sun's mean motion from the ascending node of the Moon's orbit, are set down in Table 3d. from one to 13 lunations.

These numbers for 13 lunations being added to the radical anomalies of the Sun and Moon; and to the

Sun's mean distance from the ascending node, at the time of mean new Moon in March, 1700, (Table first,) will give their mean anomalies, and the Sun's mean distance from the node, at the time of mean new Moon in March, 1701; and twelve mean lunations more with their mean anomalies, *&c.* added, will give them for the time of mean new Moon, in March, 1702.

And thus proceed to continue the Table as far as you please, always throwing off 12 signs, when their sum exceeds that number, and setting down the remainder as the proper quantity.

If the numbers belonging to 1700, (in Table first,) be subtracted from those of 1800, we shall have their whole differences in 100 complete Julian years; which accordingly we find to be 4 days, 8 hours, 10 minutes, 52 seconds, 15 thirds, and 40 fourths, with respect to the time of new Moon. These being added together 60 times, (taking care to throw off a *whole* lunation, when the days exceed twenty-nine and a half,) make up 60 centuries, or 6,000 years, as in Table 6th, which was was carried on to seconds, thirds and fourths, and then written to the nearest seconds. In the same manner were the respective anomalies, and the Sun's distance from the node found for these centurial years, and then (for want of room,) written to the nearest minutes, which is sufficiently exact for whole centuries.

By means of these two Tables, we may readily find the time of any new Moon in March, together with the anomalies of the Sun and Moon, and the Sun's mean distance from the node at these times, within the limits of 6,000 years, either before or after the 18th century; and the mean time of any new, or full Moon, in any given month after March, by means of the third and fourth Tables, within the same limits, as will be shown in the precepts for calculation.

This Table is calculated in conformity to the Old Style, for the purpose of calculating Eclipses, which have made their appearances in former ages, and likewise for those, which will take place after the year 1900, which however, are easily made to conform to the New Style.

It would be a very easy matter to calculate the time of new or full Moon, if the Sun and Moon moved equably in all parts of their orbits. But, we have already shown that their places are never the same, as they would be by equable motions, except when they are in apogee, or perigee, which is when their mean anomalies are either nothing or 6 signs. And that their mean places are always forwarder than their true, whilst the anomaly is less than 6 signs; and their true places more forward than their mean, when the anomaly is more.

Hence it is evident, that whilst the Sun's anomaly is less than 9 signs, the moon will overtake him,or be opposite to him sooner, than she would,if his motion were equable; and later whilst his anomaly is more than 6 signs. The greatest difference that can possibly happen between the mean, and true time of new, or full Moon, on account of the Sun's motion, is three hours, 48 minutes and 28 seconds; and that is when the Sun's anomaly is three signs one degree, or eight signs and 29 degrees; sooner in the first case, and later in the last. In all other signs and degrees of anomaly, the difference is gradually less, and vanishes when the anomoly is nothing, or six signs.

The Sun is in his apogee on the 30th of June, and in perigee on the 30th of December, in the present age. He is therefore, nearer the earth in our Winter than in Summer. The proportional difference of distance deduced from the Sun's apparent diameter, at these times, is as 983 to 1017.

The Moon's orbit is dilated in Winter, and contracted in Summer, therefore the lunations are longer in Winter than in Summer. The greatest difference is found to be 22 minutes and 29 seconds: the lunations are gradually increasing in length, whilst the Sun is moving from his apogee to his perigee, and decreasing in length while he is moving from his perigee to his apogee. On this account, the Moon will be later every time in coming to her conjunction with the Sun, or being in opposition to him, from December until June; and sooner from June until December, than if her orbit had continued of the same size during all the year.

These differences depend wholly on the Sun's anomaly, they are therefore put together into one Table, & called the annual, or first equation of the mean to the true syzygy.* [See Table Seventh.] This equational difference is to be subtracted from the time of the mean syzygy, when the Sun's anomaly is less than six signs, and added when it is more. At the greatest, it is 4 hours, 10 minutes, and 57 seconds; viz: 3 hours, 48 minutes and 28 seconds, on the Sun's unequal motion; and 22 minutes and 29 seconds on the account of the dilation of the Moon's orbit.

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* The word syzygy signifies both the conjunction and opposition of the Sun and Moon.

This compound equation would be sufficient, for reducing the mean time of new, or full Moon to the true, if the Moon's orbit were of a circular form, and her motion quite equable in it. But the Moon's orbit is more elliptical than the Sun's and her motion in it so much the more unequal. The difference is so great, that she is sometimes in conjunction with the Sun, or in opposition to him sooner, by 9 hours, 47 minutes and 54 seconds, than she would be, if her motion were equable; and at other times as much later. The former happens when her mean anomaly is 9 signs, and 4 degrees; and the latter, when it is 2 signs and 26 degrees. [See Table 9th.] At different distances of the Sun from the Moon's apogee, the figure of the Moon's orbit becomes different. It is longest, or most eccentric, when the Sun is in the sign and degree, either with the Moon's apogee, or perigee. Shortest, or least eccentric, when the Sun's distance from the Moon's apogee is either three signs, or nine signs; and at a mean state when the distance is either one sign and fifteen degrees; four signs and fifteen degrees; seven signs and fifteen degrees; or ten signs and fifteen degrees. When the Moon's orbit is at its greatest eccentricity, her apogeal distance from the earth's centre, is to her perigeal distance therefrom, as 1067 is to 933: when least eccentric, as 1043 is to 957; and when at the mean state as 1055 is to 945.

But the Sun's distance from the Moon's apogee is equal to the quantity of the Moon's mean anomaly, at the time of new Moon; and by the addition of 6 signs, it becomes equal in quantity to the Moon's mean anomaly, at the time of full Moon. A Table therefore will be constructed to answer all the various inequalities, depending on the different eccentricities of the Moon's orbit in the syzygies, and called the second equation of the mean, to the true syzygy. [See Table Ninth.] The Moon's anomaly when equated by Table Eighth, becomes the proper argument for taking out the second equation of time, which must be added to the former equated time, when the Moon's anomaly is less than six signs, and subtracted when the anomaly is more.

There are several other inequalities in the Moon's motion, which sometimes bring on the true syzygy a little sooner, and at other times keep it back a little later, than it would otherwise be; but they are so small that they may be all omitted except two; the former, of which [see Table 10th.] depends on the difference between the anomalies of the Sun and Moon in the syzygies; and the latter [see Table 11th.] depends on the Sun's distance from the Moon's nodes at these times. The greatest difference arising from the former is four minutes and 58 seconds; and from the latter one minute and 34 seconds. Having described the phenomena arising from the inequalities of the solar and lunar motions, we shall now explain the reasons of these inequalities.

In all calculations and observations relating to the Sun and Moon, we have considered the Sun as a moving body, and the earth as being at rest; since all the appearances are the same, whether it be the Sun, or earth that moves. But the truth is that the Sun is at rest, and the earth actually moves around him, once in every year, in the plane of the ecliptic. Therefore, whatever sign and degree of the ecliptic the earth is in at any given time, the Sun will then appear to be in the opposite sign and degree.

The nearer any body is to the Sun, the more it is attracted by him, and this attraction increases, as the square of their distances diminishes, and vice versa.

The earth's annual orbit is elliptical, and the Sun is placed in one of its foci. The remotest point of the earth's orbit is called the earth's aphelion, and the nearest point of the earth's orbit to the Sun, is called the earth's perihelion. When the earth is in its aphelion, the Sun appears to be in its apogee; and when the earth is in its perihelion, the Sun appears to be in its perigee.

As the earth moves from its aphelion to its perihelion, it is constantly more and more attracted by the Sun; and this attraction by conspiring in some degree with the motion of the earth, must necessarily accelerate its motion.

But, as the earth moves from its perihelion to its aphelion, it is continually less and less attracted by the Sun; and as their attraction acts then just as much against the earth's motion, as it has acted for it in the other half of the orbit; it retards the motion in the like degree.

The faster the earth moves, the faster will the Sun appear to move; the slower the earth moves, the slower is the Sun's apparent motion.

The Moon's orbit is also elliptical, and the earth keeps constantly in one of its focuses. The earth's attraction has the same kind of influence on the Moon's motion, that the Sun's attraction has on the motion of the earth. Therefore, the Moon's motion must be continually accelerated, whilst she is passing from her apogee to her perigee; and as gradually retarded in moving from her perigee to her apogee. At the time of new Moon, she is nearer to the Sun than the earth is at that time, by the whole semi-diameter of the Moon's orbit; which, at a mean state, is 240,000 miles; and at the full she is as many miles farther from the Sun, than the earth then is. Consequently, the Sun attaacts the Moon more than it attracts the earth, in the former case, and less in the latter. The difference is greatest, when the earth is nearest the Sun; and least when it is farthest from him. The obvious result of this is, that, as the earth is nearest to the Sun in Winter, and farthest from him in Summer; the Moon's orbit must be dilated in Winter, and contracted in Summer. These are the principal causes of the difference of time, that generally happens between the mean and true times of conjunction or opposition, of the Sun and Moon.

The other two differences, which depend on the difference between the anomalies of the Sun and Moon; and upon the Sun's distance from the lunar nodes in the syzygies, are occasioned by the different degrees of attraction of the Sun and earth upon the Moon, at greater or less distances, according to their respective anomalies, and to the position of the Moon's nodes, with respect to the same.

If it should ever happen, that the anomalies of both the Sun and Moon, were either nothing, or six signs at the mean time of new or full Moon; and the Sun should then be in conjunction with either of the Moon's nodes, all the above mentioned equations would then vanish; and the mean, and true time of the syzygy, would coincide; but if ever this circumstance did happen, we cannot expect the like again in many ages afterwards. Every 49th lunation returns very nearly to the same time of the day as before; for 49 mean lunations, wants only one minute, 30 seconds, 34 thirds of being equal to 1477 days. In 2,953,059,085,108 days, there are 100,000,000,000 lunations, exactly, and this is the smallest number of natural days, in which any exact number of mean lunations are completed.

The following Tables are calculated for the meridian of Washington, excepting Table first, which is calculated for the meridian of London, but they equally serve for any other place by adding 4 minutes to the tabular time, for every degree that the given place is eastward from WASHINGTON; or subtracting 4 minutes for every degree that the given place is westward from WASHINGTON.

These Tables also begin the day at noon, and reckon forward to the noon following, for one day. Thus, March 31st. at 22 hours, 30 minutes, and 25 seconds of tabular time, (in common reckoning,) will be April 1st. at 30 minutes, 25 seconds after ten o'clock in the morning.

Interrogations for Section Thirteenth.

Does an object appear at a less angle when far off, than when near ?

Do the Sun and Moon subtend different angles at different times ?

Are the angles subtended by the Sun and Moon once at the greatest, and once at the least in one revolution ?

Are these gradual differences the same as they would be, if those luminaries moved in circular orbits ?

Do they agree perfectly with elliptical orbits ?

Where must the lower focus of each orbit be placed to have them agree ?

What is meant by the term apogee ?

What by perigee ?

Into how many parts do Astronomers divide each orbit ?

What is meant by the distance of the Sun or Moon from any point of its orbit ?

What is the distance at any given point, of the Sun or Moon from its apogee called ?

What is the anomaly of the Sun or Moon when in apogee ?

What in perigee ?

In what part of their orbits, are the Sun and Moon continually accelerated ?

In what part retarded ?

What are the mean motions of the Sun and Moon called ?

What are the unequable called ?

In what parts of their orbits are the mean motions forward of the true ?

In what part are the true forward of the mean ?

How many signs is the anomaly in the former case ?

How many in the latter ?

Does the Moon's apogee move forward in the ecliptic ? Does it move faster or slower than the Sun's ?

Does the Moon revolve sooner from any node to the same again, than from any fixed star to the same again?

If so, what is the difference ?

What is meant by a lunation ?

Why Do Astronomers begin the year with March ?

What does Table third contain ? What Table first ?

Why was Table first calculated for Old Style ?

What is the greatest difference between the mean or true time of new or full Moon, on account of the Sun's motion?

Are the lunations longer in winter than in summer?

What reason can you advance? What the greatest difference? On what does these differences depend?

What are they called? Why is this equation not sufficient to reduce the mean time to the true?

Is the Moon's orbit more elliptical than the Sun's?

What is meant by the word syzygy?

Is the Moon sometimes sooner or later in counjunction or opposition with the Sun, than she would be if her motions were equable in every part of her orbit?

If so, what is the greatest difference? On what account does the Moon's orbit become different?

When is it the most eccentric? When the least?

What is equal to the Sun's distance from the Moon's apogee? On what does the first of these differences depend? On what the second? What is the remotest point of the earth's orbit called? What is the nearest point to the Sun called? Has the attraction of the earth any influence on the motion of the Moon? In what case is the motion continually accelerated? In what case retarded? Why is the Moon's orbit dilated in winter? Why contracted in summer? For what place are the following Tables calculated? By what means do they serve for any other place?

At what time do the Tables commence the day?

SECTION FOURTEENTH.

Precepts Relative to the following Tables.

To calculate the true time of new or full Moon, and Eclipses of the Sun or Moon, by the following Tables.

If the required new or full Moon be between the years 1800 and 1900, take out the mean time of new Moon in March, for the proposed year, from Table 16th together with the anomalies of the Sun and Moon, and the Sun's mean distance from the Moon's ascending node. But if the time of full Moon be required in March, add the half lunation at the bottom of the page, from Table 3, with its anomalies, &c. to the former numbers, if the new Moon falls before the 15th of March; but if after the 15th of March, subtract the half lunation before mentioned, with the anomalies, &c. and write down the respective remainders.

In these additions and subtractions, observe that 60 seconds make a minute, 60 minutes make a degree, 30 degrees make a sign, and 12 signs a circle.

When the number of signs exceed 12 in addition, reject 12, and set down the remainder.

When the number of signs to be subtracted is greater than the number you subtract from, add 12 signs to the minued, you will then have a remainder to set down.

When the required new, or full Moon is in any month after March, write out as many lunations, with their anomalies, and the Sun's distance from the Moon's ascending node from Table 3d. as the given month is after March, setting them regularly below the numbers taken out for March; add all these together, and they will give the mean time of the required new, or full Moon, with the mean anomalies, and the Sun's mean distance from the Moon's ascending node, which are the arguments for finding the proper equations

With the number of days of the sum; enter Table 4th under the given month, and against that number, you have the day of new, or full Moon in the left hand column; which set before the hours, minutes and seconds already found. But, (as it will sometimes happen,) if the said number of days fall short of any in the column, under the given month; add from Table 3d, one lunation, with its anomalies, &c. to the aforesaid sum, and you will then have a new sum of days, wherewith to enter Table fourth, under the given month, where you are sure to find it the second time, if the first fails. With the signs and degrees of the Sun's anomaly, enter Table 7th, and therewith take out the annual, or first equation, for reducing the mean to the true syzygy; taking care to make proportions in the Table for the odd minutes of anomaly, as the Table gives the equation only for whole degrees.

Observe in this and every other case of finding equations, that if the signs be at the head of the Table, their degrees are at the left hand, and are reckoned downwards. But if the signs be at the foot of the Table, their degrees are at the right hand, and are counted upwards; the equation being in the body of the Table, under or over the signs, in a collateral line with the degrees. The terms add, or subtract, at the head or the foot of the Tables, where the signs are found, show whether the equation is to be added to the mean time of new or full Moon, or subtracted from it. In Table 7th, the equation is to be subtracted, if the signs of the Sun's anomaly be found at the head of the Table; but it is to be added, if the signs be at the foot.

With the signs and degrees of the Sun's anomaly, at the mean time of new or full Moon, enter Table 8th, and take out the equation of the Moon's mean anomaly, subtract this equation from her mean anomaly, if the signs of the Sun's anomaly be at the head of the Table; but add it, if they be at the foot, the result will be the Moon's equated anomaly.

With the signs and degrees of the Moon's equated anomaly, enter Table 9th, and take out the second equation, for reducing the mean to the true time of new Moon, adding this equation, if the signs of the Moon's equated anomaly be at the head of the Table; but subtracting it, if they be at the foot, and the result will be the mean time of the new or full Moon, twice equated. Subtract the Moon's equated anomaly from the Sun's mean anomaly, and with the remainder, in signs and degrees; enter Table tenth, and take out the third equation, applying it to the former equated time, as the titles add, or subtract direct, and the result will be the mean time of new, or full Moon thrice equated. With the Sun's mean distance from the ascending node, enter Table 11th, and take out the equation answering to that argument; adding it to, or subtracting it from, the thrice equated time, as the titles direct; to which apply the equation of natural days, from Table 17th, subtracting it, if the clock be faster than the Sun, and adding it, if the Sun be faster than the clock, the result will be the true time of new or full Moon, and consequently of an Eclipse; agreeing with solar time.

The method of calculating an Eclipse, for any given year, will be shown further on, and a few examples compared with the precepts, will render the whole work plain, and easily understood.

The Tables begin the day at noon, and reckon forward to the noon following. They are also calculated for the latitude and longitude of WASHINGTON, excepting Table first, but serve for any place on the surface of the Globe, by subtracting four minutes for every degree that the place lies west of WASHINGTON, from the true solar time of conjunction or opposition, & adding four minutes to the true solar time for every degree that the place lies eastward of WASHINGTON, if Table 16th be used, and the same from LONDON, if Table first be used, the result will be the true solar time of the new or full moon, & consequently of an eclipse corresponding with the place for which the calculations are made.

TABLE I.—*OLD STYLE.*

The mean time, of new Moon in March, Old Style; with the mean anomalies of the Sun and Moon; and the Sun's mean distance from the moon's ascending node, from the year 1700 to 1800 inclcusive.

Year of Christ	Mean new moon in March				Sun's mean anomaly				Moon's mean anomaly				Sun smean distance from the node			
	D	H.	M.	S.	S	D.	M.	S.	S	D.	M.	S.	S	D.	M.	S.
1700	8	16	11	25	8	19	58	48	1	22	30	37	6	14	31	7
1701	27	13	44	5	9	8	20	59	0	28	7	42	7	23	14	8
1702	16	22	32	41	8	27	36	51	11	7	55	47	8	1	16	55
1703	6	7	21	18	8	16	52	43	9	17	43	52	8	9	19	42
1704	24	4	53	57	9	5	14	54	8	23	20	57	9	18	2	43
1705	13	13	42	34	8	24	30	47	7	3	9	2	9	26	5	30
1706	2	22	31	11	8	13	46	39	5	12	57	7	10	4	8	17
1707	21	20	3	50	9	2	8	50	4	18	34	13	11	12	51	18
1708	10	4	52	27	8	21	24	43	2	28	22	18	11	20	54	5
1709	29	2	25	7	9	9	46	55	2	3	59	24	0	29	37	6
1710	18	11	13	43	8	29	2	47	0	13	47	30	1	7	39	54
1711	7	20	2	20	8	18	18	39	10	23	35	36	1	15	42	41
1712	25	17	34	59	9	6	40	51	9	29	12	42	2	14	25	43
1713	15	2	23	36	8	25	56	43	8	9	0	47	3	2	28	30
1714	4	11	12	13	8	15	12	35	6	18	48	52	3	10	31	17
1715	23	8	44	52	9	3	34	47	5	24	25	57	4	19	14	18
1716	11	17	33	39	8	22	50	39	4	4	14	2	4	27	17	05
1717	1	2	22	5	8	12	6	32	2	14	2	8	5	5	19	52
1718	19	23	54	45	9	0	28	44	1	19	39	13	6	14	2	54
1719	9	8	43	22	8	19	44	37	11	29	27	18	6	22	5	41
1720	27	6	16	1	9	8	6	49	11	5	4	24	8	0	48	43
1721	16	15	4	38	8	27	22	41	9	14	52	29	8	8	51	29
1722	5	23	53	14	8	16	38	33	7	24	40	34	8	16	54	16
1723	24	21	25	54	9	5	0	45	7	0	17	40	9	25	37	18
1724	13	6	14	31	8	24	16	37	5	10	5	45	10	3	40	5
1725	2	15	3	7	8	13	32	29	3	19	53	50	10	11	42	52
1726	21	12	35	47	9	1	54	41	2	25	30	56	11	20	25	54
1727	10	21	24	23	8	21	10	34	1	5	19	1	11	28	28	41
1728	28	18	57	3	9	9	52	46	0	10	56	7	1	7	11	42
1729	18	3	45	40	8	28	48	39	10	20	44	12	1	15	14	29
1730	7	12	34	16	8	18	4	31	9	0	32	17	1	23	17	16
1731	26	10	6	56	9	6	26	42	8	6	9	23	3	2	0	17
1732	14	18	55	33	8	25	42	34	6	15	57	28	3	10	3	4
1733	4	3	44	9	8	14	58	26	4	25	45	33	3	18	5	51
1734	23	1	16	49	9	3	20	38	4	1	22	39	4	26	48	53
1735	12	10	3	25	8	22	36	30	2	11	10	44	5	4	51	40
1736	0	18	54	2	8	11	52	22	0	20	58	49	5	12	54	27
1737	19	16	26	42	9	0	14	34	11	26	35	55	6	21	37	29
1738	9	1	15	18	8	19	30	26	10	6	21	0	6	29	40	16

TABLE I.—*OLD STYLE,*

CONTINUED.

Year of Christ	Mean new moon in March				Sun's mean anomaly				Moon's mean anomaly				Sun's mean distance from the node.			
	D	H.	M.	S.	S	D.	M.	S.	S	D.	M.	S.	S.	D.	M.	S.
1739	27	22	47	58	9	7	52	38	9	12	1	6	8	8	23	18
1740	16	7	36	34	8	27	8	30	7	21	49	11	8	16	26	5
1741	5	16	25	11	8	16	24	27	6	1	37	16	8	24	28	52
1742	24	13	57	52	9	4	46	34	5	7	14	22	10	3	11	54
1743	13	22	46	27	8	24	2	27	3	17	2	27	10	18	14	41
1744	2	7	35	4	8	13	18	20	1	26	50	32	10	19	17	28
1745	21	5	7	44	9	1	40	32	1	2	27	38	11	28	0	30
1746	10	13	56	20	8	20	56	24	11	12	15	43	0	6	3	17
1747	29	11	29	0	9	9	18	36	10	17	52	49	1	14	46	19
1748	17	20	17	36	8	28	34	25	8	27	40	54	1	22	49	5
1749	7	5	6	13	8	17	50	20	7	7	23	59	2	0	51	52
1750	26	2	38	53	9	6	12	32	6	13	6	5	3	9	34	53
1751	15	11	27	29	8	25	23	24	4	22	54	10	3	17	37	40
1752	3	20	16	6	8	14	44	16	3	2	42	15	3	25	40	27
1753	22	17	48	45	9	3	6	28	2	8	19	21	5	4	23	28
1754	12	2	37	22	8	22	22	20	0	18	7	26	5	12	26	15
1755	1	11	25	59	8	11	38	12	10	27	55	31	5	20	29	2
1756	19	8	58	38	9	0	0	24	10	3	32	37	6	29	12	3
1757	8	17	47	15	8	19	16	16	8	13	20	42	7	7	14	50
1758	27	15	19	54	9	7	38	28	7	18	57	48	8	15	57	52
1759	17	0	8	31	8	26	54	20	5	23	45	54	8	24	0	39
1760	5	8	57	8	8	16	10	12	4	8	34	0	9	2	3	26
1761	24	6	29	47	9	4	32	24	3	14	11	6	10	10	46	27
1762	13	15	18	24	8	23	48	16	1	23	59	11	10	18	49	14
1763	3	0	7	1	8	13	4	8	0	3	47	16	10	26	52	1
1764	20	21	39	40	9	1	26	20	11	9	24	21	0	5	35	2
1765	10	6	28	17	8	20	42	13	9	19	12	26	0	13	37	49
1766	29	4	0	56	9	9	4	20	8	24	49	32	1	22	20	51
1767	18	12	49	33	8	28	20	17	7	4	37	37	2	0	23	38
1768	6	21	38	10	8	17	36	9	5	14	25	42	2	8	26	25
1769	25	19	10	40	9	5	58	21	4	20	2	48	3	17	9	27
1770	15	3	59	26	8	25	14	13	2	29	50	53	3	25	12	14
1771	4	12	43	2	8	14	30	5	1	9	38	58	4	3	15	1
1772	22	10	20	43	9	2	52	17	0	15	16	4	5	11	58	3
1773	11	19	9	19	8	22	8	9	10	25	4	9	5	20	0	50
1774	1	3	57	55	8	11	24	1	9	4	52	14	5	28	3	37
1775	20	1	30	25	8	29	46	13	8	10	29	20	7	6	49	38
1776	8	10	19	12	8	19	2	5	6	20	17	25	7	14	49	25
1777	27	7	51	51	9	7	24	17	5	25	54	31	8	23	32	26
1778	16	16	40	28	8	26	40	9	4	5	42	36	9	1	35	13
1779	6	1	29	4	8	15	56	1	2	15	30	41	9	9	38	0
1780	23	23	1	44	8	4	18	13	1	21	7	47	10	18	21	1
1781	13	7	50	21	8	23	34	5	0	0	55	52	10	26	23	49

TABLE I.—*OLD STYLE,*

CONCLUDED.

Year of Christ	Mean new moon in March				Sun's mean anomaly				Moon's mean anomaly				Sun's mean distance from the node			
	D	H.	M.	S.	S	D.	M.	S.	S	D.	M.	S.	S.	D.	M.	S
1782	2	16	38	57	8	12	49	58	10	10	43	57	11	4	26	35
1783	21	14	11	37	9	1	12	10	9	16	21	3	0	13	9	36
1784	9	23	0	13	8	20	28	3	7	26	9	8	0	21	12	23
1785	23	20	32	53	9	8	50	15	7	1	46	14	1	29	55	25
1786	18	5	21	30	8	28	6	7	5	11	34	19	2	7	58	12
1787	7	14	10	6	8	17	21	59	3	21	22	24	2	16	0	59
1788	25	11	42	46	9	5	44	11	2	26	59	30	3	24	44	1
1789	14	20	31	23	8	25	0	3	1	6	47	35	4	2	46	48
1790	4	5	19	59	8	14	15	55	11	16	35	40	4	10	49	25
1791	23	2	52	39	9	2	38	7	10	22	12	46	5	19	32	37
1792	11	11	41	15	8	21	53	59	9	2	0	52	5	27	55	24
1793	30	9	13	55	9	10	16	11	8	7	37	58	7	6	18	26
1794	19	18	2	32	8	29	32	3	6	17	26	4	7	14	21	13
1795	9	2	51	8	8	18	47	55	4	27	14	9	7	22	24	0
1796	27	0	23	48	9	7	10	7	4	2	51	14	9	1	7	1
1797	16	9	12	24	8	26	25	59	2	2	39	19	9	9	9	48
1798	5	18	1	1	8	15	41	51	0	22	27	23	9	17	12	35
1799	24	15	23	41	9	4	4	3	11	28	4	3	0	25	55	37
1800	3	0	22	17	8	23	19	55	10	7	52	30	1	3	58	24

TABLE II.

The first new Moon, with the mean anomalies of the Sun and Moon, and the Sun's mean distance from the ascending node, next, after complete centuries of Julian years.

Julian Years.	D	H	M	S	S	D	M	S	D	M	S	D	M
100	4	8	10	52	0	3	21	8	15	22	4	19	27
200	8	16	21	44	0	6	42	5	0	44	9	8	55
300	13	0	32	37	0	10	3	1	16	6	1	28	22
400	17	8	43	29	0	13	24	10	1	28	6	17	49
500	21	16	54	21	0	16	46	6	16	50	11	7	16
600	26	1	5	14	0	20	7	3	2	12	3	26	44
700	0	20	32	3	11	24	22	10	21	45	7	15	31
800	5	4	42	55	11	27	43	7	7	7	0	4	58
900	9	12	53	47	0	1	4	3	22	29	4	24	25
1000	13	21	4	40	0	4	25	0	7	51	9	13	53
2000	27	18	9	19	0	8	50	0	15	42	6	27	45
3000	12	2	29	56	11	14	8	11	27	43	3	10	58
4000	25	23	34	35	11	18	33	0	5	34	0	24	50
5000	10	7	55	12	10	23	52	11	17	36	9	8	3
6000	24	4	59	52	10	28	17	11	25	27	6	21	56

TABLE III.

Mean anomalies of the Sun and Moon, and the Sun's mean distance from the node, for 13 and ½ mean lunations.

No. of lunations.	mean lunations.				Sun's mean anomaly				Moon's mean anomaly.				Sun's mean dist. from the node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
1	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
2	59	1	28	6	1	28	12	39	1	21	38	1	2	1	20	29
3	88	14	12	9	2	27	18	58	2	17	27	1	3	2	0	43
4	118	2	56	12	3	26	25	17	3	13	16	2	4	2	40	56
5	147	15	40	15	4	25	31	37	4	9	5	2	5	3	21	10
6	177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
7	206	17	8	21	6	23	44	15	6	0	43	3	7	4	41	38
8	236	5	52	24	7	22	50	35	6	26	32	3	8	5	21	52
9	265	18	36	27	8	21	56	54	7	22	21	4	9	6	2	6
10	295	7	20	30	9	21	3	14	8	18	10	4	10	6	42	20
11	324	20	4	33	10	20	9	33	9	13	59	5	11	7	22	34
12	354	8	48	36	11	19	15	52	10	9	48	5	0	8	2	47
13	383	21	32	40	0	18	22	12	11	5	37	6	1	8	41	1
½ lunations.	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7

☞ *The half lunation above, is used in finding the mean time of full Moon, and likewise in calculating her Eclipses.*

TABLE IV.

The days of the Year, reckoned from the beginning of March.

Days.	March.	April.	May.	June.	July.	August.	September	October.	November.	December.	January	February.
1	1	32	62	93	123	154	185	215	246	276	307	338
2	2	33	63	94	124	155	186	216	247	277	308	339
3	3	34	64	95	125	156	187	217	248	278	309	340
4	4	35	65	96	126	157	188	218	249	279	310	341
5	5	36	66	97	127	158	189	219	250	280	311	342
6	6	37	67	98	128	159	190	220	251	281	312	343
7	7	38	68	99	129	160	191	221	252	282	313	344
8	8	39	69	100	130	161	192	222	253	283	314	345
9	9	40	70	101	131	162	193	223	254	284	315	346
10	10	41	71	102	132	163	194	224	255	285	316	347
11	11	42	72	103	133	164	195	225	256	286	317	348
12	12	43	73	104	134	165	196	226	257	287	318	349
13	13	44	74	105	135	166	197	227	258	288	319	350
14	[illegible]	[illegible]	75	106	136	167	198	228	259	289	320	351
15	[illegible]	46	76	107	137	168	199	229	260	290	321	352
16	[illegible]	[illegible]	77	108	138	169	200	230	261	291	322	353
17	[illegible]	[illegible]	78	109	139	170	201	231	262	292	323	354
18	18	49	79	110	140	171	202	232	263	293	324	355
19	19	[illegible]	80	111	141	172	203	233	264	294	325	356
20	20	51	81	112	142	173	204	234	265	295	326	357
21	21	52	82	113	143	174	205	235	266	296	327	358
22	22	53	83	114	144	175	206	236	267	297	328	359
23	23	54	84	115	145	176	207	237	268	298	329	360
24	24	55	85	116	146	177	208	238	269	299	330	361
25	25	56	86	117	147	178	209	239	270	300	331	362
26	26	57	87	118	148	179	210	240	271	301	332	363
27	27	58	88	119	149	180	211	241	272	302	333	364
28	28	59	89	120	150	181	212	242	273	303	334	365
29	29	60	90	121	151	182	213	243	274	304	335	
30	30	61	91	122	152	183	214	244	275	3 5	336	
31	31	00	92		153	184		245		306	337	

TABLE V.

THE SUN'S DECLINATION.

ARGUMENT.—The Sun's true place.

Degrees	Signs. 0. N. 6 S.		Signs. 1. N. 7 S.		Signs. 2. N. 8 S.		Degrees
	D.	M.	D.	M.	D.	M.	
0	0	0	11	30	20	11	30
1	0	24	11	51	20	24	29
2	0	48	12	11	20	36	28
3	1	12	12	32	20	48	27
4	1	36	12	53	20	59	26
5	1	59	13	13	21	10	25
6	2	23	13	33	21	21	24
7	2	47	13	53	21	31	23
8	3	11	14	12	21	41	22
9	3	34	14	31	21	50	21
10	3	58	14	50	21	59	20
11	4	22	15	9	22	8	19
12	4	45	15	28	22	16	18
13	5	9	15	46	22	24	17
14	5	32	16	4	22	31	16
15	5	55	16	22	22	38	15
16	6	18	16	39	22	45	14
17	6	41	16	57	22	51	13
18	7	4	17	14	22	56	12
19	7	27	17	30	23	2	11
20	7	50	17	46	23	6	10
21	8	13	18	2	23	11	9
22	8	35	18	18	23	14	8
23	9	57	18	33	23	18	7
24	9	20	18	48	23	21	6
25	9	42	19	3	22	23	5
26	10	4	19	17	23	25	4
27	10	25	19	31	23	27	3
28	10	47	19	45	23	28	2
29	11	8	19	58	23	29	1
30	11	30	20	11	23	29	0
Degrees.	Signs. 11 S. 5 N.		Signs. 10 S. 4 N.		Signs. 9 S. 3 N.		Degrees.

TABLE VI.

Equation of the Sun's centre, or the difference between his mean and true place.

ARGUMENT---Sun's mean anomaly.

Degrees.	Subtract.																		Degrees
	0 Signs.			1 Sign.			2 Signs.			3 Signs.			4 Signs.			5 Signs.			
	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S	D	M	S	
0	0	0	00	0	56	47	1	39	6	1	55	37	1	41	12	0	55	30	30
1	0	1	59	0	58	30	1	40	7	1	55	3	1	40	1	0	57	7	29
2	0	3	57	1	0	12	1	41	0	1	55	38	1	39	10	0	55	19	28
3	0	5	5	1	1	53	1	42	3	1	55	36	1	38	6	0	53	30	27
4	0	7	5	1	3	3	1	42	59	1	55	31	1	37	0	0	51	40	26
5	0	9	5	1	5	19	1	43	5	1	55		1	35	[illegible]	0	49	49	25
6	0	11	[illegible]	1	[illegible]	50	1	44	4	1	55	15	1	34	43	0	47	57	24
7	0	13	48	1	8	27	1	45	34	1	55	03	1	33	32	0	46	05	23
8	0	15	46	1	10	9	1	46	2	1	54	50	1	32	19	0	44	11	22
9	0	17	43	1	11	30	1	47	8	1	54	35	1	31	4	0	42	16	21
10	0	19	40	1	13	9	1	47	59	1	54	17	1	29	47	0	40	21	20
11	0	21	37	1	14	41	1	48	55	1	53	57	1	28	[illegible]	0	35	25	19
12	0	23	33	1	16	11	1	49	15	1	53	35	1	27	9	0	33	28	13
13	0	25	29	1	17	40	1	49	54	1	53	12	1	25	48	0	34	30	17
14	0	27	25	1	19	8	1	50	30	1	52	46	1	24	[illegible]	0	32	32	16
15	0	29	20	1	20	34	1	51	5	1	52	13	1	23	0	0	30	33	15
16	0	31	15	1	21	59	1	51	37	1	51	43	1	21	31	0	28	33	14
17	0	33	9	1	23	22	1	52	8		51	15	1	20	6	0	26	33	13
18	0	35	2	1	24	44	1	52	30	1	50	41	1	18	3	0	24	33	12
19	0	36	55	1	26	5	1	53	[illegible]	1	50	5	1	17	5	0	22	32	11
20	0	38	47	1	27	24	1	53	27	1	49	26	1	[illegible]	33	0	20	30	10
21	0	40	39	1	28	4	1	53	50	1	[illegible]	[illegible]	1	13	59	0	18	23	9
22	0	42	30	1	29	57	1	54	[illegible]		48	3	1	12	[illegible]	0	16	26	8
23	0	44	20	1	31	[illegible]	1	54	28	1	47	19	1	10	47	0	14	24	7
24	0	46	9	1	32	[illegible]	1	54	4	1	46	[illegible]	1	9	9	0	12	21	6
25	0	47	57	1	33	3	1	54	5	1	45	4	1	7	2		10	1	5
26	0	49	45	1	34	45	1	55	1	1	44	[illegible]	1	5	4	0	[illegible]	[illegible]	4
27	0	51	32	1	35	53	1	55	20	1	44	1	1	4	7	0	6	11	3
28	0	53	18	1	36	59	1	55	28	1	43	7	1	2	24	0	4	7	2
29	0	55	3	1	38	3	1	55	3	1	42	10		0	[illegible]	0	2	4	1
30	0	56	47	1	39	6	1	55	37	1	41	12	0	58	53	0	0	0	0
Degrees	11 Signs.			10 Signs.			9 Signs.			8 Signs.			7 Signs.			6 Signs.			Degrees.
	Add.																		

TABLE VII.

The annual, or first equation of the mean, to the true syzygy.

ARGUMENT---Sun's mean anomaly.

Degrees.	Subtract.																		Degrees.
	0 Signs.			1 Sign.			2 Signs.			3 Signs.			4 Signs.			5 Signs.			
	H	M	S	H	M	S	H	M	S	H	M	S	H	M	S	H	M	S	
0	0	0	0	2	3	12	3	35	0	4	10	53	3	39	30	2	7	45	30
1	0	4	18	2	6	55	3	37	10	4	10	57	3	37	19	2	3	55	29
2	0	8	35	2	10	36	3	39	18	4	10	55	3	35	6	2	0	1	28
3	0	12	51	2	14	14	3	41	23	4	10	45	3	32	50	1	56	5	27
4	0	17	8	2	17	52	3	43	26	4	10	39	3	30	30	1	52	6	26
5	0	21	24	2	21	27	3	45	25	4	10	24	3	28	5	1	48	4	25
6	0	25	39	2	25	09	3	47	19	4	10	4	3	25	35	1	41	1	24
7	0	23	55	2	28	29	3	49	7	4	9	39	3	23	0	1	39	56	23
8	0	34	11	2	31	57	3	50	50	4	9	10	3	20	20	1	35	49	22
9	0	33	25	2	35	22	3	52	29	4	8	37	3	17	35	1	31	41	21
10	0	42	29	2	38	44	3	54	4	4	7	59	3	14	49	1	27	31	20
11	0	46	52	2	42	3	3	55	35	4	7	16	3	11	59	1	23	19	19
12	0	51	4	2	45	13	3	57	2	4	6	29	3	9	6	1	19	5	18
13	0	55	17	2	48	30	3	58	27	4	5	37	3	6	10	1	14	49	17
14	0	59	27	2	51	40	3	59	49	4	4	41	3	3	10	1	10	33	16
15	1	3	36	2	54	48	3	1	7	4	3	40	3	0	7	1	6	15	15
16	1	7	45	2	57	53	4	2	18	4	2	35	2	57	0	1	1	56	14
17	1	11	53	3	0	54	4	3	23	4	1	26	2	53	49	0	57	36	13
18	1	16	0	3	3	51	4	4	22	4	0	12	2	50	36	0	53	15	12
19	1	20	6	3	6	45	4	5	18	3	58	52	2	47	18	0	48	52	11
20	1	24	10	3	9	36	4	6	10	3	57	27	2	43	57	0	44	28	10
21	1	23	12	3	12	24	4	6	58	3	55	59	2	40	33	0	40	2	9
22	1	32	12	3	15	9	4	7	41	3	54	26	2	37	6	0	35	36	8
23	1	36	10	3	17	51	4	8	21	3	52	49	2	33	35	0	31	10	7
24	1	40	6	3	20	30	4	8	57	3	51	9	2	30	2	0	26	44	6
25	1	41	1	3	23	5	4	9	29	3	49	26	2	26	26	0	22	17	5
26	1	47	54	3	25	36	4	9	55	3	47	35	2	22	47	0	17	50	4
27	1	51	46	3	28	3	4	10	16	3	45	44	2	19	5	0	13	23	3
28	1	55	37	3	30	26	4	10	33	3	43	45	2	15	20	0	8	56	2
29	1	59	26	3	32	45	4	10	45	3	41	40	2	11	35	0	4	29	1
30	2	3	12	3	35	0	4	10	53	3	39	30	2	7	45	0	0	0	0
Degrees.	11 Signs.			10 Signs.			9 Signs.			8 Signs.			7 Signs.			6 Signs.			Degrees.
	Add.																		

TABLE VIII.

EQUATION OF THE MOON'S MEAN ANOMALY.

ARGUMENT---Sun's mean anomaly.

Degrees.	Subtract.																		Degrees.
	0 Signs.			1 S gn.			2 Signs.			3 Signs.			4 Signs.			5 Sigus.			
	H	M	S	H	M	S	H	M	S	H	M	S	H	M	S	H	M	S	
0	0	0	0	0	46	45	1	21	32	1	35	1	1	23	4	0	48	19	30
1	0	1	37	0	48	10	1	22	21	1	35	2	1	22	14	0	46	51	29
2	0	3	13	0	49	34	1	23	10	1	35	1	1	21	24	0	45	23	28
3	0	4	52	0	50	53	1	23	57	1	35	0	1	20	32	0	43	54	27
4	0	6	28	0	52	19	1	24	41	1	34	57	1	19	38	0	42	24	26
5	0	8	6	0	53	40	1	25	24	1	34	50	1	18	42	0	40	53	25
6	0	9	42	0	55	0	1	26	6	1	34	43	1	17	45	0	39	21	24
7	0	11	20	0	56	21	1	26	48	1	34	33	1	16	48	0	37	49	23
8	0	12	56	0	57	38	1	27	28	1	34	22	1	15	47	0	36	15	22
9	0	14	33	0	58	56	1	28	6	1	34	9	1	14	44	0	34	40	21
10	0	16	10	1	0	13	1	33	43	1	33	53	1	13	41	0	33	5	20
11	0	17	47	1	1	29	1	29	17	1	33	37	1	12	37	0	31	31	19
12	0	19	23	1	2	43	1	29	51	1	33	20	1	11	33	0	29	54	18
13	0	20	59	1	3	56	1	30	22	1	33	0	1	10	26	0	28	18	17
14	0	22	35	1	5	8	1	30	50	1	32	38	1	9	17	0	26	40	16
15	0	24	10	1	6	18	1	31	19	1	32	14	1	8	8	0	25	3	15
16	0	25	45	1	7	27	1	31	45	1	31	50	1	6	58	0	23	23	14
17	0	27	19	1	8	36	1	32	12	1	31	23	1	5	46	0	21	45	13
18	0	28	52	1	9	42	1	32	34	1	30	55	1	4	32	0	20	7	12
19	0	30	25	1	10	49	1	32	57	1	30	25	1	3	19	0	18	28	11
20	0	31	57	1	11	54	1	33	17	1	29	54	1	2	1	0	16	48	10
21	0	33	29	1	12	58	1	33	36	1	29	20	1	0	45	0	15	8	9
22	0	35	2	1	14	1	1	33	52	1	28	45	0	59	26	0	13	28	8
23	0	36	32	1	15	1	1	34	6	1	28	9	0	58	7	0	11	48	7
24	0	38	1	1	16	0	1	34	18	1	27	30	0	56	45	0	10	7	6
25	0	39	29	1	16	59	1	34	30	1	26	50	0	55	23	0	8	20	5
26	0	40	59	1	17	57	1	34	40	1	26	27	0	54	1	0	6	44	4
27	0	42	26	1	18	52	1	34	48	1	25	5	0	52	37	0	5	3	3
28	0	43	54	1	19	47	1	34	54	1	24	39	0	51	12	0	3	21	2
29	0	45	19	1	20	40	1	34	58	1	23	52	0	49	45	0	1	40	1
30	0	47	45	1	21	32	1	35	1	1	23	4	0	48	19	0	0	0	0
Degrees.	11 Signs.			10 Signs.			9 Signs.			8 Signs.			7 Signs			6 Signs.			Degrees.
	Add.																		

TABLE IX.

The second equation of the mean, to the true syzygy.

ARGUMENT.--Moon's equated anomaly.

Add

Deg	0 Signs.			1 Signs.			2 Signs.			3 Signs.			4 Signs.			5 Signs.			Deg
	H.	M.	S.	H.	M.	S.	H.	M.	S	H.	M.	S.	H.	M.	S	H.	M.	S.	
0	0	0	0	5	12	48	8	47	8	9	46	44	8	8	59	4	34	33	30
1	0	10	58	5	21	56	8	51	45	9	45	3	8	3	12	4	26	1	29
2	0	21	56	5	30	57	8	56	10	9	45	12	7	57	23	4	17	25	28
3	0	32	54	5	39	51	9	0	25	9	44	11	7	51	35	4	8	47	27
4	0	43	52	5	48	37	9	4	31	9	42	59	7	45	46	4	0	7	26
5	0	54	50	5	57	17	9	8	25	9	41	36	7	39	46	3	51	23	25
6	1	5	48	6	5	51	9	12	9	9	40	3	7	33	36	3	42	3	24
7	1	16	46	6	14	19	9	15	43	9	38	19	7	27	22	3	33	38	23
8	1	27	44	6	22	41	9	19	5	9	36	24	7	21	2	3	24	42	22
9	1	38	40	6	30	57	9	22	14	9	34	18	7	14	36	3	15	44	21
10	1	49	33	6	39	4	9	23	12	9	32	1	7	7	56	3	6	45	20
11	2	0	23	6	47	0	9	27	54	9	29	33	7	1	2	2	57	43	19
12	2	11	10	6	54	46	9	30	32	9	26	54	6	54	8	2	48	39	18
13	2	21	54	7	2	24	9	32	58	9	24	4	6	47	9	2	39	34	17
14	2	32	34	7	9	52	9	35	12	9	21	3	6	40	6	2	30	28	16
15	2	43	9	7	17	9	9	37	14	9	17	51	6	32	56	2	21	19	15
16	2	53	38	7	24	19	9	39	8	9	14	28	6	25	40	2	12	8	14
17	3	4	3	7	31	18	9	40	51	9	10	54	6	18	18	2	2	53	13
18	3	14	24	7	38	9	9	42	21	9	7	9	6	10	49	1	53	36	12
19	3	24	42	7	44	51	9	43	42	9	3	13	6	3	16	1	44	16	11
20	3	34	58	7	51	24	9	44	53	8	59	6	5	55	38	1	34	54	10
21	3	45	11	7	57	45	9	45	52	8	54	50	5	47	54	1	25	31	9
22	3	55	21	8	3	56	9	46	38	8	50	24	5	40	4	1	16	7	8
23	4	5	26	8	9	57	9	47	13	8	45	48	5	32	9	1	6	41	7
24	4	25	26	8	15	46	9	47	36	8	41	2	5	24	9	0	57	13	6
25	4	25	20	8	21	24	9	47	49	8	36	6	5	16	5	0	47	44	5
26	4	35	6	8	26	53	9	47	54	8	31	0	5	7	56	0	38	13	4
27	4	44	42	8	32	11	9	47	46	8	25	44	4	59	42	0	28	41	3
28	4	54	11	8	37	19	9	47	33	8	20	18	4	51	15	0	19	8	2
29	5	3	33	8	42	18	9	47	14	8	14	33	4	43	2	0	9	34	1
30	5	12	48	8	47	8	9	46	44	8	8	59	4	34	33	0	0	3	0
Deg	11 Signs			10 Signs			9 Signs			8 Signs			7 Signs			6 Signs			Deg

Subtract

TABLE X.

The third equation of the mean, to the true syzygy.

ARGUMENT--Sun's mean anomaly—Moon's equated ancmaly.

Degrees.	Signs.		Signs.		Signs.		Degrees.
	0 Signs, subtract. 6 Signs, add.		1 Sign, subtract. 7 Signs, add.		2 Signs, subtract. 8 Signs, add.		
	M	S	M	S	M	S	
0	0	0	2	22	4	12	30
1	0	5	2	26	4	15	29
2	0	10	2	30	4	18	28
3	0	15	2	34	4	21	27
4	0	20	2	38	4	24	26
5	0	25	2	42	4	27	25
6	0	30	2	46	4	30	24
7	0	35	2	50	4	32	23
8	0	40	2	54	4	34	22
9	0	45	2	58	4	36	21
10	0	50	3	2	4	38	20
11	0	55	3	6	4	40	19
12	1	0	3	10	4	42	18
13	1	5	3	14	4	44	17
14	1	10	3	18	4	46	16
15	1	15	3	22	4	48	15
16	1	20	3	26	4	50	14
17	1	25	3	30	4	51	13
18	1	30	3	34	4	52	12
19	1	35	3	38	4	53	11
20	1	40	3	42	4	54	10
21	1	45	3	45	4	55	9
22	1	49	3	48	4	56	8
23	1	52	3	51	4	57	7
24	1	56	3	54	4	57	6
25	2	0	3	57	4	57	5
26	2	4	4	0	4	58	4
27	2	9	4	3	4	58	3
28	2	13	4	6	4	58	2
29	2	18	4	9	4	58	1
30	2	22	4	12	4	58	0
Degrees.	Signs. 5 Signs, subtract. 11 Signs, add.		Signs. 4 Signs, subtract. 10 Signs, add.		Signs. 3 Signs, subtract. 9 Signs, add.		Degrees.

TABLE XI.

The fourth equation of the mean, to the true Syzygy.

ARGUMENT—The sun's mean distance from the node.

Add.

Degrees.	0 Signs. 6 Signs.		1 Sign. 7 Signs.		2 Signs. 8 Signs.		Degrees.
	M.	S.	M.	S.	M.	S.	
0	0	0	1	22	1	22	30
1	0	4	1	23	1	21	29
2	0	7	1	24	1	20	28
3	0	10	1	25	1	18	27
4	0	13	1	26	1	16	26
5	0	16	1	27	1	14	25
6	0	20	1	28	1	12	24
7	0	23	1	29	1	10	23
8	0	26	1	30	1	8	22
9	0	29	1	31	1	6	21
10	0	32	1	32	1	3	20
11	0	35	1	33	1	0	19
12	0	38	1	33	0	57	18
13	0	41	1	34	0	54	17
14	0	44	1	34	0	51	16
15	0	47	1	34	0	49	15
16	0	50	1	34	0	45	14
17	0	52	1	34	0	41	13
18	0	54	1	34	0	37	12
19	0	57	1	33	0	34	11
20	1	0	1	38	0	31	10
21	1	2	1	32	0	28	9
22	1	5	1	31	0	25	8
23	1	8	1	30	0	22	7
24	1	10	1	29	0	19	6
25	1	12	1	28	0	16	5
26	1	14	1	27	0	13	4
27	1	16	1	26	0	10	3
28	1	18	1	25	0	6	2
29	1	20	1	24	0	3	1
30	1	22	1	22	0	0	0
	5 Signs. 11 Signs.		4 Signs. 10 Signs.		3 Signs. 9 Signs.		

Subtract.

TABLE XII.

THE SUN'S MEAN LONGITUDE—MOTION AND ANOMALY.

	Sun's mean Longitude				Sun's mean anomaly.			
Years beginning.	S	D	M	S	S	D	M	S
Old Style 1	9	7	53	10	6	28	48	
201	9	9	23	50	6	26	57	
301	9	10	9	10	6	26	1	
401	9	10	54	30	6	25	5	
501	9	11	39	50	6	24	9	
1001	9	15	26	30	6	19	32	
1101	9	16	11	50	6	18	36	
1201	9	16	57	10	6	17	40	
1301	9	17	42	30	6	16	44	
1401	9	18	27	50	6	15	49	
1501	9	19	13	10	6	14	53	
1601	9	19	58	30	6	13	57	
1701	9	20	43	50	6	13	1	
1801	9	21	29	10	6	12	6	
N.S.1797	9	10	37	33	6	1	8	17
1798	9	10	23	13	6	0	52	51
1799	9	10	8	54	6	0	37	26
1800	9	9	54	35	6	0	22	1
1801	9	9	40	16	6	0	6	36
1802	9	9	25	56	5	29	51	10
1803	9	9	11	37	5	29	35	45
1804	9	9	56	26	6	0	19	28
1805	9	9	42	6	6	0	4	2
1806	9	9	27	48	5	29	48	38
1807	9	9	13	29	5	29	33	13
1808	9	9	58	17	6	0	16	48
1809	9	9	43	57	6	0	1	31
1810	9	9	29	37	5	29	45	57
1811	9	9	15	17	5	29	30	32
1812	9	10	0	5	6	0	14	15
1813	9	9	45	45	5	29	58	49
1814	9	9	31	25	5	29	43	26
1815	9	9	17	5	5	29	27	58
1816	9	10	1	53	6	0	11	41
1817	9	9	47	33	5	29	56	15
1818	9	9	33	13	5	29	40	50
1819	9	9	18	53	5	29	25	24
1820	9	10	3	41	6	0	9	7
1821	9	9	49	22	5	29	55	42

TABLE XII.—CONTINUED.

THE SUN'S MEAN LONGITUDE—MOTION AND ANOMALY.

Sun's mean Motion--Sun's mean anomaly.

Years complete.	S	D	M	S	S	D	M
1	11	29	45	40	11	29	45
2	11	29	31	21	11	29	29
3	11	29	17	20	11	29	14
4	0	0	1	50	11	29	58
5	11	29	47	31	11	29	42
6	11	29	33	11	11	29	27
7	11	29	18	52	11	29	11
8	0	0	3	41	11	29	55
9	11	29	49	21	11	29	40
10	11	29	35	2	11	29	24
11	11	29	20	42	11	29	9
12	0	0	5	31	11	29	53
13	11	29	51	12	11	29	37
14	11	29	36	52	11	29	22
15	11	29	22	33	11	29	7
16	0	0	7	22	11	29	50
17	11	29	53	2	11	29	35
18	11	29	38	43	11	29	20
19	11	29	24	23	11	29	4
20	0	0	9	12	11	29	48
40	0	0	18	24	11	29	37
60	0	0	27	36	11	29	26
80	0	0	36	48	11	29	15
100	0	0	46	0	11	29	4
200	0	1	32	0	11	28	8
300	0	2	18	0	11	27	12
400	0	3	4	0	11	26	16
500	0	3	50	0	11	25	21
600	0	4	32	0	11	24	25
700	0	5	17	20	11	23	29
800	0	6	2	40	11	22	33
900	0	6	48	0	11	21	37
1000	0	7	40	0	11	20	41
2000	0	15	20	0	11	11	22
3000	0	22	40	0	11	2	3
4000	1	0	13	20	10	22	44
5000	1	7	46	40	10	13	25
6000	1	15	20	0	10	4	6

TABLE XII.—CONTINUED.

THE SUN'S MEAN LONGITUDE—MOTION AND ANOMALY.

Sun's mean Motion---Sun's mean anomaly.

MONTHS.	S	D	M	S	S	D	M
January,	0	0	0	0	0	0	8
February,	1	0	33	18	1	0	33
March,	1	28	9	11	1	28	9
April,	2	28	42	30	2	28	42
May,	3	28	16	40	3	28	17
June,	4	28	49	58	4	28	50
July,	5	28	24	8	5	28	24
August,	6	28	57	26	6	28	57
September,	7	29	30	44	7	29	30
October,	8	29	4	54	8	29	4
November,	9	29	38	12	9	29	37
December.	10	29	12	22	10	29	11

Sun's mean motion & anomaly--Sun's mean motion & anomaly.

DAYS	S	D	M	S	DAYS	S	D	M	S
1	0	0	59	8	17	0	16	45	22
2	0	1	58	17	18	0	17	44	30
3	0	2	57	25	19	0	18	43	38
4	0	3	56	33	20	0	19	42	47
5	0	4	55	42	21	0	20	41	55
6	0	5	54	50	22	0	21	41	3
7	0	6	53	58	23	0	22	40	12
8	0	7	53	7	24	0	23	39	20
9	0	8	52	15	25	0	24	38	28
10	0	9	51	23	26	0	25	37	37
11	0	10	50	32	27	0	26	36	45
12	0	11	49	40	28	0	27	35	53
13	0	12	48	48	29	0	28	35	2
14	0	13	47	57	30	0	29	34	10
15	0	14	47	5	31	0	30	33	18
16	0	15	46	13					

TABLE XII.—CONCLUDED.

THE SUN'S MEAN LONGITUDE—MOTION AND ANOMALY.

Sun's mean motion and anomaly.

	Sun's mean motion and anomaly.			Sun's mean dist. from the Node.				Sun's mean motion snd anomaly.			Sun's mean dist. from the Node.		
H M S	D M s	M s 3ds	S 3ds 4ths	D M s	M S T	S T F	H M S	D M S	M S T	S T F	D M S	M S T	S T F
1	0	2	28	0	2	36	31	1	16	23	1	20	30
2	0	4	56	0	5	12	32	1	18	51	1	23	6
3	0	7	24	0	7	48	33	1	21	19	1	25	42
4	0	9	51	0	0	23	34	1	23	47	1	28	18
5	0	12	19	0	12	59	35	1	26	15	1	30	54
6	0	14	47	0	15	35	36	1	28	42	1	33	29
7	0	17	15	0	18	11	37	1	31	10	1	36	5
8	0	19	43	0	20	47	38	1	33	38	1	38	40
9	0	22	11	0	23	23	39	1	36	6	1	41	16
10	0	24	28	0	25	58	40	1	38	34	1	43	52
11	0	27	6	0	28	34	41	1	41	2	1	46	28
12	0	29	34	0	31	10	42	1	43	30	1	49	44
13	0	32	2	0	33	45	43	1	45	57	1	51	39
14	0	34	30	0	36	21	44	1	48	25	1	54	15
15	0	36	58	0	38	57	45	1	50	53	1	55	51
16	0	39	26	0	41	33	46	1	53	21	1	59	27
17	0	41	53	0	44	8	47	1	55	49	2	2	3
18	0	44	21	0	46	44	48	1	58	17	2	4	39
19	0	46	49	0	49	20	49	2	0	44	2	7	13
20	0	49	17	0	51	56	50	2	3	12	2	9	50
21	0	51	45	0	54	32	51	2	5	40	2	12	25
22	0	54	13	0	57	8	52	2	8	8	2	15	2
23	0	56	40	0	59	43	53	2	10	36	2	17	38
24	0	59	8	1	2	19	54	2	13	4	2	20	14
25	1	1	36	1	4	55	55	2	15	32	2	22	50
26	1	4	4	1	7	31	56	2	17	59	2	25	26
27	1	6	32	1	10	7	57	2	20	27	2	28	2
28	1	9	0	1	12	43	58	2	22	55	2	30	38
29	1	11	28	1	15	19	59	2	25	23	2	33	14
30	1	13	55	1	17	55	60	2	27	51	2	35	50

☞ In Leap-Year after February, add one day, and one day's motion.

TABLE XIII.

Equation of the Sun's mean distance from the Node.

ARGUMENT---Sun's mean anomaly.

Degrees.	Subtract												Degrees.
	0 Signs.		1 Sign.		2 Signs		3 Signs		4 Signs		5 Signs.		
	D	M	D	M	D	M	D	M	D	M	D	M	
0	0	0	I	2	1	47	2	5	I	50	1	4	30
1	0	2	I	4	1	48	2	5	I	48	1	2	29
2	0	4	I	6	1	49	2	5	I	47	1	0	28
3	0	6	I	8	1	50	2	5	I	46	0	58	27
4	0	9	I	10	1	51	2	5	I	45	0	56	26
5	0	11	I	12	1	52	2	5	I	44	0	54	25
6	0	13	I	14	1	53	2	5	I	43	0	52	24
7	0	15	I	16	1	54	2	4	I	41	0	50	23
8	0	17	I	17	1	55	2	4	I	40	0	48	22
9	0	19	I	18	1	56	2	4	I	38	0	46	21
10	0	21	I	19	1	57	2	4	I	37	0	44	20
11	0	23	I	21	1	58	2	3	I	36	0	42	19
12	0	25	I	22	1	58	2	3	I	34	0	40	18
13	0	28	I	24	1	59	2	3	I	33	0	37	17
14	0	30	I	26	2	0	2	2	I	31	0	35	16
15	0	32	I	27	2	0	2	2	I	30	0	33	15
16	0	34	I	28	2	1	2	1	I	28	0	31	14
17	0	36	I	30	2	1	2	1	I	27	0	29	13
18	0	38	I	31	2	2	2	0	I	25	0	27	12
19	0	40	I	34	2	2	2	0	I	24	0	24	11
20	0	42	I	35	2	3	1	59	I	23	0	22	10
21	0	44	I	36	2	3	1	59	I	21	0	20	9
22	0	46	I	37	2	4	1	58	I	19	0	18	8
23	0	48	I	39	2	4	1	57	I	17	0	16	7
24	0	50	I	40	2	4	1	56	I	15	0	13	6
25	0	52	I	41	2	4	1	55	I	13	0	11	5
26	0	54	I	43	2	5	1	54	I	11	0	9	4
27	0	56	I	44	2	5	1	53	I	9	0	7	3
28	0	58	I	45	2	5	1	52	I	3	0	5	2
29	1	0	I	46	2	5	1	51	I	6	0	3	1
30	1	2	I	47	2	5	1	50	I	4	0	0	0
Degrees.	11 Signs		10 Signs		9 Signs		8 Signs		7 Signs		6 Signs		Degrees.
	Add.												

TABLE XIV.

THE MOON'S LATITUDE IN ECLIPSES.

ARGUMENT---Moon's Equated Distance from the Node.

0 Signs—North Ascending.
6 Signs—South Ascending.

Degrees.	D	M	S	Degrees.
0	0	0	0	30
1	0	5	15	29
2	0	10	30	28
3	0	15	45	27
4	0	20	59	26
5	0	26	13	25
6	0	31	26	24
7	0	36	39	23
8	0	41	51	22
9	0	47	22	21
10	0	52	13	20
11	0	57	23	19
12	1	2	31	18
13	1	7	38	17
14	1	12	44	16
15	1	17	49	15
16	1	22	52	14
17	1	27	53	13
18	1	32	52	12
19	1	37	49	11

FIVE SIGNS.
NORTH DESCENDING.

ELEVEN SIGNS.
SOUTH DESCENDING.

This Table shows the Moon's true Latitude a little beyond the utmost limits of Eclipses.

TABLE XIV.

The Moon's horizontal parallax, with the semi-diameters, and the true horary motions of the Sun and Moon, to every sixth degree of their mean anomalies; the quantities for the intermediate degrees, being easily proportioned by sight.

Anomaly of the Sun and Moon.		Moon's horizontal parallax.		Sun's Semi-Diameter.		Moon's Semi-Diameter.		Moon's Horary Motion.		Sun's Horary Motion.		Anomaly of the Sun and Moon.	
S	D	M	S	M	S	M	S	M	S	M	S	S	D
0	0	54	29	15	50	14	54	30	10	2	23	12	0
0	6	54	31	15	50	14	55	30	12	2	23	11	24
0	12	54	34	15	50	14	56	30	15	2	23	11	18
0	18	54	40	15	51	14	57	30	19	2	23	11	12
0	24	54	47	15	51	14	58	30	26	2	23	11	6
1	0	54	56	15	52	14	59	30	34	2	24	11	0
1	6	55	6	15	53	15	1	30	44	2	24	10	24
1	12	55	17	15	54	15	4	30	55	2	24	10	18
1	18	55	29	15	55	15	8	31	09	2	24	10	12
1	24	55	42	15	56	15	12	31	23	2	25	10	6
2	0	55	56	15	58	15	17	31	40	2	25	10	0
2	6	56	12	15	59	15	22	31	56	2	26	9	24
2	12	56	29	16	1	15	26	32	17	2	27	9	18
2	18	56	48	16	2	15	30	32	39	2	27	9	12
2	24	57	8	16	4	15	36	33	11	2	28	9	6
3	0	57	30	16	6	15	41	33	23	2	28	9	0
3	6	57	52	16	8	15	47	33	47	2	29	8	24
3	12	58	12	16	10	15	52	34	11	2	29	8	18
3	18	58	31	16	11	15	58	34	24	2	29	8	12
3	24	58	49	16	13	16	3	34	58	2	30	8	6
4	0	59	6	16	14	16	9	35	22	2	30	8	0
4	6	59	21	16	15	16	14	35	45	2	31	7	24
4	12	59	35	16	17	16	19	36	0	2	31	7	18
4	18	59	48	16	19	16	24	36	20	2	32	7	12
4	24	60	0	16	20	16	28	36	40	2	32	7	6
5	0	60	11	16	21	16	31	37	0	2	32	7	0
5	6	60	21	16	21	16	32	37	10	2	33	6	24
5	12	60	30	16	22	16	37	37	19	2	33	6	18
5	18	60	38	16	22	16	38	37	28	2	33	6	12
5	24	60	45	16	23	16	39	37	36	2	33	6	6
6	0	60	45	16	23	16	39	37	40	2	33	6	0

TABLE XVI.

MEAN NEW MOON, &c. IN MARCH, NEW STYLE, FROM 1800 TO 1900 INCLUSIVE: CALCULATED FOR THE MERIDIAN OF WASHINGTON. 76 DEGREES AND 56 MINUTES WEST LONGITUDE FROM LONDON.

Year of chris:	Mean new Moon.				Sun's mean anomaly.				Moon's mean anomaly.				Sun's mean distance from the node·			
	D	H.	M.	S.	S	D.	M.	S.	S	D.	M.	S.	S.	D.	M.	S.
1800	24	19	14	3	3	23	19	55	10	7	52	36	11	3	58	24
1801	14	4	3	2	3	12	35	47	8	17	40	41	11	12	1	10
1802	3	12	51	4	3	1	51	39	6	27	28	46	11	20	3	57
1803	22	10	24	2	3	20	13	51	6	3	5	52	0	28	46	58
1804	10	19	13	2	3	9	29	43	4	12	53	57	1	6	49	45
1805	0	4	1	3	7	28	45	31	2	22	42	2	1	14	52	35
1806	19	1	34	1	3	17	7	43	1	28	19	8	2	23	35	36
1807	8	10	22	55	3	6	23	35	0	8	7	13	3	1	38	23
1808	26	7	55	35	3	24	45	47	11	13	44	19	4	10	21	24
1809	15	16	44	11	3	14	1	39	9	23	32	24	4	18	24	11
1810	5	1	32	48	3	3	17	31	8	3	20	29	4	26	26	58
1811	23	23	5	2	3	21	39	43	7	8	57	35	6	5	9	59
1812	12	7	54	4	3	10	55	35	5	18	45	40	6	13	12	46
1813	1	16	42	41	3	0	11	27	3	28	33	45	6	21	15	23
1814	20	14	15	2	3	18	33	39	3	4	10	51	7	29	58	24
1815	9	23	3	57	3	7	53	31	1	13	58	5	8	8	1	11
1816	27	20	36	37	3	26	15	43	0	19	36	9	9	16	44	12
1817	17	5	25	13	3	15	31	35	10	29	24	7	9	24	46	59
1818	6	14	13	50	3	4	47	27	9	9	12	12	10	2	49	46
1819	25	11	46	29	3	23	9	39	8	14	49	18	11	11	32	47
1820	13	20	35	[illegible]	3	12	25	31	6	24	37	23	11	19	35	34
1821	3	5	23	45	3	1	41	23	5	4	25	23	11	27	38	21
1822	22	2	56	22	3	20	3	35	4	10	2	29	1	6	22	22
1823	11	11	44	59	3	9	19	27	2	19	50	34	1	14	25	9
1824	29	9	17	39	3	27	41	39	1	25	27	40	2	23	9	10
1825	18	18	6	15	3	16	57	31	0	5	15	45	3	1	11	57

TABLE XVI—Continued.

Year of Christ.	Mean new Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean distance from the Node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
1826	8	2	54	52	8	6	13	23	10	15	3	50	3	9	14	44
1827	27	0	27	31	8	24	35	35	9	20	40	56	4	17	58	45
1828	15	9	16	8	8	13	51	27	8	0	29	1	4	26	1	32
1829	4	18	4	45	8	3	7	19	6	10	17	6	5	4	4	19
1830	23	15	37	24	8	21	29	31	5	15	54	12	6	12	48	20
1831	13	0	26	1	8	10	45	23	3	25	42	17	6	20	51	7
1832	1	9	14	37	8	0	1	15	2	5	30	22	6	28	53	54
1833	20	6	47	17	8	18	23	27	1	11	7	28	8	7	37	55
1834	9	15	35	54	8	7	39	19	11	20	55	33	8	15	40	42
1835	28	13	8	33	8	26	1	31	10	26	32	39	9	24	24	43
1836	16	21	57	10	8	15	17	23	9	6	20	44	10	2	27	30
1837	6	6	45	46	8	4	33	15	7	16	8	49	10	10	30	17
1838	25	4	18	26	8	22	55	27	6	21	45	55	11	19	14	18
1839	14	13	7	2	8	12	11	19	5	1	34	0	11	27	17	5
1840	2	21	55	39	8	1	27	11	3	11	22	5	0	5	19	52
1841	21	19	28	19	8	19	49	23	2	16	59	11	1	14	3	53
1842	11	4	16	55	8	9	5	15	0	26	47	16	1	22	6	40
1843	30	1	49	35	8	27	27	27	11	32	24	22	3	0	50	41
1844	18	10	38	12	8	16	43	19	10	12	12	27	3	8	53	28
1845	7	19	26	48	8	5	59	11	8	22	0	32	3	16	56	15
1846	26	16	59	28	8	24	21	23	7	27	37	38	4	25	40	16
1847	16	1	48	5	8	13	37	15	6	7	25	43	5	3	43	3
1848	4	10	36	41	8	2	53	7	4	17	13	48	5	11	45	50
1849	23	8	9	21	8	21	15	19	3	22	50	54	6	20	29	51
1850	12	16	57	57	8	10	31	11	2	2	38	59	6	28	32	38
1851	2	1	46	33	7	29	47	3	0	12	27	4	7	6	35	25
1852	19	23	19	13	8	18	9	15	11	18	4	10	8	15	19	26
1853	9	8	7	49	8	7	25	7	9	27	52	15	8	23	22	13
1854	28	5	40	29	8	25	47	19	9	3	29	21	10	2	6	14
1855	17	14	29	5	8	15	3	11	7	13	17	26	10	10	9	1

TABLE XVI—CONTINUED.

Year of Christ.	Mean new Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Snn's mean distance from the Node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
1856	5	23	17	42	8	4	19	2	5	23	5	31	10	18	11	48
1857	24	20	50	22	8	22	41	15	4	28	42	37	11	26	55	49
1858	14	5	38	58	3	11	57	7	3	8	30	42	0	4	58	36
1859	3	14	27	35	8	1	12	59	1	18	18	47	0	13	1	23
1860	21	12	0	15	8	19	35	11	0	23	55	53	1	21	45	24
1861	10	20	48	51	8	8	51	3	11	3	43	58	1	29	48	11
1862	29	18	21	31	8	27	13	15	10	9	21	4	3	8	32	12
1863	19	3	10	7	8	16	29	7	8	19	9	9	3	16	34	59
1864	7	11	58	44	8	5	45	0	6	28	57	14	3	24	37	46
1865	26	9	31	24	8	24	7	12	6	4	34	20	5	3	21	47
1866	15	18	20	0	8	13	23	4	4	14	22	25	5	11	24	34
1867	5	3	8	37	8	2	38	56	2	24	10	30	5	19	27	21
1868	23	0	41	16	8	21	1	8	1	29	47	36	6	28	11	22
1869	12	9	29	53	8	10	17	0	0	9	35	41	7	6	14	9
1870	1	18	18	30	7	29	32	52	10	19	23	46	7	14	16	56
1871	20	15	51	9	8	17	55	4	9	25	0	5	8	23	0	57
1872	9	0	39	46	8	7	10	56	8	4	48	10	9	1	3	44
1873	27	22	12	26	8	25	33	8	7	10	25	16	10	9	47	45
1874	17	7	1	2	8	14	49	0	5	20	13	21	10	17	50	32
1875	6	15	49	39	8	4	4	52	4	0	1	26	10	25	53	19
1876	24	13	22	18	8	22	27	4	3	5	38	32	0	4	37	20
1877	13	22	10	55	8	11	42	56	1	15	26	37	0	12	40	7
1878	3	6	59	32	8	0	58	48	11	25	14	42	0	20	42	54
1879	22	4	32	11	8	19	21	0	11	0	51	48	1	29	26	55
1880	10	13	20	48	8	8	36	52	9	10	39	53	2	7	29	42
1881	29	10	53	28	8	26	59	5	8	16	16	59	3	16	13	43
1882	18	19	42	4	8	16	14	57	6	26	5	4	3	24	16	30
1883	8	4	30	41	8	5	30	49	5	5	53	9	4	2	19	17
1884	26	2	3	20	8	23	53	1	4	11	30	15	5	11	3	18
1885	15	10	51	57	8	13	8	53	2	21	18	20	5	19	6	5

TABLE XVI—CONCLUDED.

Year of Christ.	Mean new Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean distance from the Node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
1886	4	19	40	33	8	2	24	45	1	1	6	25	5	27	8	52
1887	23	17	13	13	8	20	46	57	0	6	43	31	7	5	52	53
1888	12	2	1	50	8	10	2	49	10	16	31	36	7	13	55	40
1889	1	10	50	26	7	29	18	41	8	26	19	41	7	21	58	27
1890	20	8	23	6	8	17	40	53	8	1	56	47	9	0	42	28
1891	9	17	11	43	8	6	56	45	6	11	44	52	9	8	45	15
1892	27	14	44	22	8	25	18	57	5	17	21	58	10	17	2	24
1893	16	23	32	59	8	14	34	49	3	27	10	3	10	25	32	3
1894	6	8	21	35	8	3	50	41	2	6	58	8	11	3	34	50
1895	25	5	54	15	8	22	12	53	1	12	34	14	0	11	18	51
1896	13	14	42	52	8	11	28	45	11	22	22	19	0	19	21	33
1897	2	23	31	28	8	0	44	37	10	2	10	24	0	27	24	25
1898	21	21	4	9	8	19	6	49	9	7	46	30	2	6	8	26
1899	11	5	52	44	8	8	22	41	7	17	34	35	2	14	11	13
1900	30	3	25	24	8	26	44	53	6	23	10	41	3	22	55	14

The year 1900, will not be Leap-Year. the difference then will be 13 days, between the Old and New Style.

TABLE XVII.

A concise Equation Table, adapted to the second year after Leap-Year, within one minute of the truth, for every year, (excepting the second) showing to the nearest full minute, how much a Clock should be faster or slower than the Sun.

Months.	Days.	Equation in Minutes.	
January,	1	4	Clock faster than the Sun.
	3	5	
	5	6	
	7	7	
	9	8	
	12	9	
	15	10	
	18	11	
	21	12	
	25	13	
	31	14	
February,	10	15	
	21	14	
	27	13	
March,	4	12	
	8	11	
	12	10	
	15	9	
	19	8	
	22	7	
	25	6	
	29	5	

Months.	Days.	Equation in Minutes.	
April,	1	4	Clock f. S.
	4	3	
	7	2	
	10	1	
	15	0	
	19	1	Clock slower.
	24	2	
	30	3	
May,	13	4	
	29	3	
June,	5	2	
	10	1	
	15	0	
	20	1	Clock faster.
	25	2	
	29	3	
July,	5	4	
	11	5	
	28	6	

Months.	Days.	Equation in Minutes.	
August,	9	5	Clock faster,
	13	4	
	20	3	
	24	2	
	28	1	
	31	0	
September,	3	1	Clock slower than the Sun.
	6	2	
	9	3	
	12	4	
	15	5	
	18	6	
	21	7	
	24	8	
	27	9	
	30	10	
October,	3	11	
	6	12	
	10	13	
	14	14	
	19	15	

Months.	Days.	Equation in Minutes.	
October,	27	16	Clock slower than the Sun.
November,	15	15	
	20	14	
	24	13	
	27	12	
	30	11	
December,	2	10	
	5	9	
	7	8	
	9	7	
	11	6	
	13	5	
	16	4	
	18	3	
	20	2	
	22	1	
	24	0	
	26	1	C. faster.
	28	2	
	30	3	

☞This Table is near enough to the truth, for regulating common Clocks and Watches, and was for that purpose calculated by Mr. Smeaton.

SECTION FIFTEENTH.

EXAMPLES.

EXAMPLE I.

Required the true time of new Mooon in July, 1832, and also whether there were an Eclipse of the Sun or not.

	Mean new Moon.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean dist from the Node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
Mean new Moon in March 1832.	1	9	14	37	8	0	1	15	2	5	30	22	6	28	53	54
5 lunations.	147	15	40	15	4	25	31	37	4	9	5	2	5	3	21	10
	149	0	54	52	0	25	32	52	6	14	35	24	0	2	14	04
from Table 7		1	46	9	6	13	55	6			40	18	Argument 4th.			
time once eq'td.	26	23	8	43	4	11	37	42	6	13	55	6				
Table 9th.		2	12	8	Argument 2.				Argument 3d.							
	26	20	56	35												
Table 10th.			3	38												
	26	20	52	57												
Table 11th.				49												
	26	20	53	46												
Eq'tn. of the			6													
Sun's centre.	26	20	47	46												

Equal to the 27th day of July, 8 hours, 47 minutes, and 46 seconds in the morning, at WASHINGTON ;- the true time of new Moon. The Sun being then only two degrees and 14 minutes from the Moon's ascending node, was consequently eclipsed.

EXAMPLE II.

Required the true time of new Moon in May, 1836, and whether there will be an Eclipse of the Sun or not.

	Mean new Moon in March, 1836.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's m. dist. from the node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
1836	16	21	57	10	8	15	17	23	9	6	20	44	10	2	27	30
Table 3d	59	1	28	6	1	28	12	39	1	21	38	1	2	1	20	28
	14	23	15	16	10	13	30	2	10	27	53	45	0	3	47	58
Table 7th.		2	54	24	10	29	6	47		1	8	2				
	15	2	19	40	11	14	23	15	10	29	6	47				
Table 9th.		5	21	56												
	14	20	57	44												
Table 10th.			1	20												
	14	20	59	4												
Table 11th.				13												
	14	20	59	17												
Table 17th.			4	1												
	14	21	3	18												

Equal to the 15th day of May, 9 hours, 3 minutes, and 18 seconds; true time of new Moon at WASHINGTON. The Sun being then only 13 degrees and 48 minutes from the Moon's Node, the Sun will consequently be visibly eclipsed.

EXAMPLE III.

Required the true time of New Moon, in December, in the year 1850; and whether there will be an Eclipse at that time or not.

Mean New Moon in March, 1850.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean distance from the Node.			
D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
12	16	57	57	8	10	31	11	2	2	38	59	6	28	32	38
265	18	36	27	8	21	56	54	7	22	21	4	9	6	2	6
3	11	34	24	5	2	28	5	9	25	0	3	4	4	34	44
	1	58	3	9	24	15	25			44	38				
3	9	36	21	7	8	12	40	9	24	15	25				
	9	11	13												
3	0	25	8												
		2	54												
3	0	28	2												
		1	27												
3	0	26	35												
		9	42												
3	0	36	7												

True time of new Moon in December, 1850, will be the 3d. 36*m*—17*s*, afternoon. The Sun will then be more than 56 degrees from the node, and consequently there can be no Eclipse at that time.

EXAMPLE I.

Required the true time of full moon in July 1833, and whether or not there will be an eclipse of the moon, at that time.

Mean new Moon in March				Sun's mean anomaly				Moon's mean anomaly				Sun's mean distance from the node			
D	H.	M.	S.	S	D.	M.	S.	S	D.	M.	S.	S	D.	M.	S.
20	6	47	17	8	18	23	27	1	11	7	28	8	7	37	55
38	14	12	9	2	27	18	58	2	17	27	1	3	2	0	42
14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
1	15	21	28	0	0	15	35	10	11	28	59	11	24	58	44
		1	7	10	11	28	34				25				
1	15	20	21	1	18	47	1	10	11	28	34				
	7	42	8												
1	7	33	13												
		3	38												
1	7	34	35												
			16												
1	7	34	19												
		3	22												
1	7	37	41												

in the afternoon.

=To the first day of July, 1833 the true time of full moon in the longitude of Washington, at 7 hours 37 minutes and 41 seconds in the afternoon, the sun, being then within five degrees at a mean rate from the Moon's node, consequently the Moon will then be eclipsed.

Required the true time of full Moon in April, in the year 1836 at Rochester; and also, whether there will be an eclipse of the Moon, or not.

The true time of full Moon, in April, in the year 1836, will be on the first day, 5 hours 19 minutes and 53 seconds in the afternoon, in the longitude of Rochester; the sun will then be more than 40 degrees from the Moon's node, and consequently there will be no eclipse on that day.

EXAMPLE VII.

Required the true time of full Moon, in September in the year 1848, in the longitude of Utica; and whether there will be an eclipse at that time.

Meen time of full Moon in March				Sun's mean anomaly.				Moon's mean anomaly.				Sun's mean distance from the node.			
D	H.	M.	S.	S	D,	M.	S	S	D.	M.	S.	S	D.	M.	S.
4	10	36	41	8	2	53	7	4	17	13	48	5	11	45	53
177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
12	9	23	1	2	12	4	13	4	5	2	21	0	1	7	21
	3	57	2	4	3	32	30		1	29	51				
12	5	25	59	10	8	31	43	4	3	32	30				
	7	48	40												
12	13	14	39												
		3	46												
12	13	18	25												
			5												
12	13	18	30												
		4	8												
12	13	22	38	True time at Lyons.											
		6													
12	13	28	38	True time at Utica.											

The Moon will be full in the year 1848, on the 13th day of September, at 1 o'clock and 28 minutes in the morning, in the longitude of Utica. the Sun, then will be only one degree and seven minutes from the Moon's node; the Moon therefore, will be eclipsed at that time.

To calculate the true time of any new, or full Moon, and consequently Eclipses, in any given year and month, between the commencement of the Christian Era, and that of the 18th Century.

Find a year of the same number in the 18th Century, with that of the year in the proposed Century from Table First; and take out the mean time of New Moon in March, Old Style, for that year; with the mean anomalies of the Sun and Moon, and the Sun's mean distance from the node at that time, as before instructed. Take as many complete Centuries of years from Table Second as when subtracted from the year of the 18th Century, the remainder will answer to the given year, with the anomalies, and Sun's distance from the node; subtract these from those of the 18th Century, and the remainder will be the mean time of new Moon in March, with the anomalies, *&c.* for the proposed year; then proceed, in all respects, for the true time of new or full Moon, as shown in the Precepts, or former Examples.

If the day's annexed to these Centuries, exceed the number of daysfr om the beginning of March, taken out in the 18th Century, subtract a lunation, and its anomalies, *&c.* from Table 3d, to the time, and anomalies of new Moon in March, and then proceed as above stated—this circumstance happens in Example Fifth.

EXAMPLE IV.

Required the true time of New Moon in June, in the year of Christ, 36, at the City of JERUSALEM.

BY THE PRECEPTS	Mean N. Moon in March.				Sun's mean Anomaiy.				Moon's mean Anomaly.				Sun's mean dist. from the Node.			
	D	H	M	S	D	D	M	S	S	D	M	S	S	D	M	S
					S	D	M	S								
March, 1736.	0	18	54	2	8	11	52	22	8	20	58	49	5	12	24	27
Add one lunation.	9	12	44	9	0	29	6	19	0	25	49	0	1	9	40	14
Last n. moon, March 173	30	7	38	5	9	10	58	41	1	16	47	49	6	13	34	41
Subtract 1700 years.	9	19	11	25	8	19	58	48	1	22	30	37	6	14	31	7
mean n.moon March in 36	21	15	26	40	0	20	59	53	11	24	17	12	21	29	3	34
Add three lunations.	38	14	12	9	2	27	18	58	2	17	27	1	3	2	0	42
By Table Fourth=		110														
June	18	5	38	49	3	18	18	50	2	11	44	13	3	1	4	16
First equation.		3	54	43	Arg for 1st eqt.					1	30	55				
	18	1	39	00	3	13	18	51	2	10	13	18	3	1	4	16
		9	24	15	2	10	13	18	Arg. 2d. eqtion.				Arg. 4 h eqt'n			
	18	11	3	21	1	8	5	33								
Third equation.			2	54	Arg. 3d. eqt'n											
	18	11	0	28												
				3												
True time of New Moon	18	11	0	24												
at LONDON.		2	20													
True time at JERUSALEM	18	13	20	24												

The true time of New Moon in June, in the year of our Lord, 36, on the 19th day, at one hour, 20 minutes and 24 seconds, in the morning.

The mean distance of the Sun being 3 signs, 1 degree, 4 minutes, and 16 seconds from the Moon's ascending node, consequently there was no Eclipse at that time.

To calculate the true time of new, or full Moon, and also to know whether there will be an Eclipse at the time, in any given year and month before the Christian Era. Find a year in the 18th Century from Table 1st. which being added to the given number of years before Christ diminished by one, shall make a number of complete Centuries. Find this number of Centuries in Table second, and subtract the time, anomalies and distances from the node belonging to it, from those of the mean new Moon in March, the above found year, in the 18th Century, and the remainder will denote the time, and anomalies, &c. of the mean new Moon in March, the given year, before Christ, ; then for the true time thereof in any month of that year, proceed as before directed.

EXAMPLE V.

Required the true time of new Moon in May, Old Style, the year before Christ, 585, at ALEXANDRIA, in EGYPT. The year 584, added to 1716, make 2300, or 23 Centuries.

	Mean N. Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean distance from the Node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
March, 1716.....	11	17	33	29	8	22	50	39	4	4	14	2	4	27	17	5
March, 2000.....	27	18	9	1.	0	8	50	0	0	15	42	0	6	27	45	0
Do. 300.....	13	0	32	37	0	10	3	0	1	16	6	0	1	28	22	0
	40	18	52	56	0	18	53	0	2	1	48	0	8	26	07	0
Subtract 1 lunation..	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
New Moon, 2300,....	11	5	58	53	11	19	46	41	1	5	59	0	7	25	26	46
Which sub't. from 1716 March, B. C. 585...	0	11	34	36	9	3	03	58	2	28	15	2	9	1	50	19
Add 3 lunations....	88	14	12	9	2	27	18	58	2	17	27	1	3	2	0	42
New Moon March 58	28	1	46	45	0	0	22	56	5	15	42	3	0	3	51	01
First equation....			1	37	Argt. 1st. eqt'n.							46				
	28	1	45	08	0	0	22	56	5	15	41	17	0	3	51	01
					5	15	41	17	Argt, 2d. eq'tn.							
	28	1	45	08	6	14	41	39	5	15	41	17	0	3	51	1
Second equation....		2	15	1	Arg't. 3d. eqt'n.											
	28	4	00	9	6	14	41	39	5	15	41	17	0	3	51	1
Third equation....			1	9									Argt. 4th. eqt'n.			
	28	4	01	18												
Fourth equation...				12												
	28	4	1	30												
Clock slower....			3													
Time at LONDON....	28	4	4	30												
Difference of longitude.		2	2													
May........	28	6	6	30												

The true time of new Moon at ALEXANDRIA in May, 585 years before Christ, was on the 28th day, 6 hours, 6 minutes and 30 seconds, afternoon. The Sun being then only three degrees and 51 minutes from the Moon's ascending node; was consequently eclipsed.

The above Eclipse was central, and total in NORTH AMERICA at eleven o'clock in the morning; it also passed centrally over the south parts of FRANCE and ITALY. The duration of total darkness being about 3 minutes.

EXAMPLE VIII.

Required the true time of full Moon, at Alexandria in Egypt, in September, Old Style, in the year 201 before the Christian Era. 200 years added to 1800, make 2000, or 20 Centuries.

By the Precepts	Mean n. Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's dis. frm the Moon's ascnd'g node			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
March, 1800.	13	0	22	17	8	23	19	55	10	7	52	36	11	8	58	24
Add 1 lunation.	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
From the same,	42	13	06	20	9	22	26	14	11	3	41	36	0	4	38	38
Subtract 2000 yr's.	27	18	9	19	0	8	50	0	0	15	42	0	6	27	45	0
m. n. moon b.C.201	14	18	57	01	9	13	36	14	10	17	59	36	5	6	53	38
Add 6 lunations.	177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
	191==															
n.m. Sept. b.C.201	7	23	21	19	3	8	14	10	3	22	53	39	11	10	55	2
Add ½ lunation,	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
full moon Sep. 201	22	17	43	21	3	22	47	20	10	5	48	9	11	26	15	9
First equation.		3	52	6	Arg. 1st. eqt.					1	28	14				
Time once eqt'd.	22	13	52	15	3	22	47	20	10	4	19	55	11	26	15	9
Second equation.		8	25	4	10	4	19	55	Arg. 2d. eqt.							
Time twice eqt'd.	22	5	26	11	5	18	27	25	10	4	19	55	11	26	15	9
Third equation.				58	Arg. 3d. eqt.								Arg. 4th eqt.			
	22	5	25	13												
				12												
true T. at London	22	5	25	1												
add for diff of long		2	2													
	22	7	27	1												
Add S. Clock.			7	33												
True Time at Alexandria.	22	7	34	34												

The true time of full Moon, at Alexandria in Egypt in the year before Christ, 201, in September, was on the 22d day, 7 hours, 34 minutes, and 34 seconds, the actual time of opposition. The Sun being within three degrees and 45 minutes of the Moon's ascending node, consequently the Moon was visibly eclipsed at that time at ALEXANDRIA.

To calculate the true time of new or full Moon, and Eclipses in any given year; and month after the 18th Century.

Find a year of the same number in the 18th century with that of the year proposed, and take out the mean time, and anomalies *&c* of new moon in March, old style, from table first for that year.

Take so many years from table second, as when added to the above mentioned year in the 18th century will answer to the given year in which the new, or full moon is required; and take out the first new Moon with its anomalies &c for these complete centuries. Add all these together, and then proceed as before directed, to reduce the mean to the true syzygy. It is however necessary to remember, to subtract a lunation with its anomalies, when the above said addition carries the new Moon beyond the 31st day of March, as in the following example.

EXAMPLE IX.

Required the true time of New Moon in July, old style, 2180 at Washington.

Four centuries added, to 1780 make 2180.

	New Moon in March				Sun's mean anomalies				Moon's mean anomalies.				Sun's distance from the node.			
By the precepts.	D.	H.	M.	S	S.	D.	M.	S.	S.	D.	M.	S.	S.	D.	M.	S.
March 1780	23	23	1	44	9	4	18	13	1	21	7	47	10	18	21	1
add 400 years	17	8	43	29	0	13	24	0	10	1	28	0	6	17	49	0
Subtract 1 lunation	41	7	45	13	9	17	42	13	11	22	35	47	5	6	10	1
	29	12	44	3	0	29	6	19	0	25	49	0	1	0	49	14
Mean time new Moon March 2180	11	19	1	10	8	18	35	54	10	26	46	47	4	5	29	47
add 4 lunations	118	2	56	12	3	26	25	17	3	13	16	2	4	2	40	56
	129															
N. M. July 2180	7	21	57	22	0	15	1	11	2	10	2	49	8	8	10	43
First equation		1	3	39	Arg. 1st eqt.						24	12				
Time once equated	7	20	53	43	0	15	1	11	2	9	38	37	8	8	10	43
Second equation		9	24	8	2	9	38	37	Arg. 2nd eqt				Arg. 4th eqt			
	8	6	17	51	10	5	22	34								
Third equation,			3	56	Arg. 3d eqt.											
	8	6	21	47												
Fourth equation			1	8												
	8	6	22	55												
F. Clock			4	30												
T. time at London	8	6	18	25												
Difference of long.		5	8													
True time at Washington the present Capitol of the U. S.	8	1	10	25												

The true of time New Moon, old style, will then be on the 8th day of July, 1 hour 10 minutes and 25 seconds after noon; or the 22d day, at the same hour minute and second new style.

EXAMPLE IX.

Required the Sun's true place, March 20th, 1764 O. Style, at 22 hours, 30 minutes, 25 seconds past noon. In common reckoning, March 21st, at 10 hours 30 minutes and 25 seconds in the morning.

	Sun's Long.				Sun's Anmly			
	S	D	M	S	S	D	M	S
To the Radical year after Christ, ...1701	9	20	43	50	6	13	1	0
Add complete years, ...60	0	0	27	12	11	29	26	0
3	11	29	17	0	11	29	14	0
March, ...	1	28	9	11	1	28	9	0
Bissextile days, ...20	0	20	41	55	0	20	41	55
Hours, ...22			54	13			54	13
Minutes, ...30			1	14			1	14
Seconds, ...25				1				1
Sun's mean place at the given time, ...	0	10	14	36	9	1	27	23
Add equation of the Sun's centre, from table 6,		1	55	36	The Argm'nt			
Sun's true place, ...	0	12	10	12	with which			
That is Aries, 12 deg's. 10 minutes, 12 sec'ds.					enter table 6.			

EXAMPLE XI.

Required the Sun's true place, October 23, O. Style, at 16 hours, 57 minutes past noon, in the 4008th year before Christ I. which was the 4007th year before the year of his birth, and the year of the Julian period, 706. This is supposed by some to be the very instant of the Creation.

BY THE PRECEPTS.		Sun's Long				Sun's anomy			
		S	D	M	S	S	D	M	S
From the Radical number after Christ,........		9	7	53	10	6	28	48	0
Subtract for 5000 complete years, ...		1	7	46	40	10	13	25	0
Remains for a new Radix, ...		8	0	6	30	8	15	23	0
To which add .... Complete years,	900	0	6	48	0	11	21	37	0
	80	0	0	36	16	11	29	15	0
	12	0	0	5	26	11	29	15	0
October		8	29	4	54	8	29	4	0
Days,...............		0	22	40	12	0	22	40	12
Hours, ...				39	26			39	26
Minutes, ...				2	20			2	20
Sun's mean place at the given time, ...		6	0	3	4	5	28	33	58
Subtract equation of the Sun's centre,.				3	4	Argt. eqt'n.			
Sun's true place at that time, ...		6	0	0	0	Sun's centre			
Which was just entering the Sign LIBRA.									

Concerning Eclipses of the Sun & Moon.

To find the Sun's true distance from the Moon's ascending node, at the time of any given new or full Moon, and consequently to know whether there be an Eclipse at that time or not.

The Sun's mean distance from the Moon's ascending node, is the Argument for finding the Moon's fourth equation in the syzygies, and therefore it is taken into all the foregoing Examples, in finding the true times thereof. Thus at the time of mean new Moon in March, 1764, Old Style, or April in the new, the Sun's mean distance from the ascending node, is 0 signs, 35 minutes, 2 seconds. [See Table First.] The descending node is opposite to the ascending one, and consequently are exactly 6 signs distant from each other. When the Sun is within 17 degrees of either of the nodes at the time of new Moon ; he will be eclipsed at that time, as before stated, and at the time of full Moon, if the Sun be within 12 degrees of either node, she will be eclipsed. Thus we find from Table First, that there was an Eclipse of the Sun, at the time of new Moon, April 1st. at 30 minutes, 25 seconds after 10 in the morning at LONDON, New Style, when the old is reduced to the new, and the mean time reduced to the true.

It will be found by the Precepts, that the true time of that new Moon is 50 minutes, 46 seconds later, than the mean time, and therefore we must add the Sun's motion from the node during that interval to the above mean distance 0s. 6d. 35m. 2s. which motion is found in Table Twelfth, for 50 minutes and 46 seconds to be 2 minutes, 12 seconds, and to this apply the equation of the Sun's mean distance from the node in Table 13th, which at the mean time of new Moon, April 1st. 1764, is 9 signs, 1 degree, 26 minutes, and 20 seconds, and we shall have the Sun's true distance from the node at the true time of new Moon, as follows :

Sun from node.

	S	D	M	S
At the mean time of N.Moon in April, 1764,	0	5	35	2
Sun's motion from node for 50 minutes,			2	10
For 46 seconds,				2
Sun's mean dist from node at true N. Moon,	0	5	37	14
Equation from mean dist from node, add,		2	5	0
Sun's true dist. from the ascending node,	0	7	42	14

Which being far within the above named limits of 17 degrees, the Sun was at that time eclipsed. The manner of projecting this or any other Eclipse, either of the Sun or Moon, will now be shown.

SECTION SIXTEENTH.

To Project an Eclipse of the Sun.

To project an Eclipse of the Sun, we must from the Tables find the ten following Elements :

1st. The true time of conjunction of the Sun and Moon, and

2d. The semi-diameter of the earth's disk, as seen from the Moon, at the true time of conjunction ; which is equal to the Moon's horizontal parallax.

3d. The Sun's distance from the solstitial colure, to which he is then nearest.

4th. The Sun's declination.

5th. The angle of the Moon's visible path with the ecliptic.

6th. The Moon's latitude.

7th. The Moon's true horary motion from the Sun.

8th. The Sun's semi-diameter,

9th. The Moon's semi-diameter.

10th. The semi-diameter of the penumbra.

EXAMPLE XII.

Required the true time of New Moon at LONDON, in April, 1764, New Style, and also whether there were an Eclipse of the Sun or not at that time; and likewise the elements necessary for its protraction, if there were at that time an Eclipse.

By the Precepts.	mean time of New Moon in March.				Sun's mean anomaly.				Moons mean anomaly.				Sun's mean dist'. from the node.			
	D	H	M	S	S	D	M	S	S	D	M	S	S	D	M	S
March 1764	2	8	55	36	8	2	20	0	10	13	35	21	11	4	54	48
Add 1 lunation	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
Mean New Moon	31	21	39	39	9	1	26	19	11	9	24	21	0	5	35	2
First equation		4	10	40	Arg 1st eqt'n					1	34	57				
	32	1	50	19	9	1	26	19	11	10	59	18				
Second equation.		3	24	49	11	10	59	18	Arg 2nd eqt'							
	31	22	25	30	9	20	27	1	11	10	59	18	0	5	35	2
Third equation			4	37	Arg 3d eqt'n								Arg 4th eqt'			
	31	22	30	7									Sun from node			
				18												
True New Moon	31	22	30	25									0	5	35	2
Equation of days			3	48												
	31	22	26	35												

The true time is April 1st, 10 hours, 26 minutes, 35 seconds in the morning, tabular time. The mean distance of the Sun at that time, being only 5 degrees, 35 minutes and 2 seconds past the ascending node, the Sun was at that time eclipsed. Now proceed to find the elements, necessary for its protraction. The true time being found as above.

To find the Moon's horizontal parallax, or semi-diameter of the Earth's disk as seen from the Moon.—

Enter Table 15th with the signs and degrees of the Moon's anomaly, (making proportion because the anomaly is in the Table calculated only to every 6th degree,) and from it take out the Moon's horizontal parallax, which for the above time is 54 minutes, and 53 seconds, answering to the anomaly of 11s. 9d. 24m. 21 seconds.

To find the Sun's distance from the nearest solstice, namely, the beginning of Cancer, which is 3 signs, or 90 degrees from the beginning of Aries. It appears from Example 1st. for calculating the Sun's true place, the calculation being made for the same time, that the Sun's longitude from the beginning of Aries, was then 0s. 12d. 10m. 12 seconds, that is, the Sun's place was then in Aries, 12 degrees, 10m. 12 seconds, therefore

	S	D	M	S
from	3	0	0	0
Subtract the Sun's longitude or place.		12	10	12
Remains Sun's distance from the solstice,	2	17	49	48

Which is equal to 77 degrees, 49 minutes, 48 seconds, each sign containing 30 degrees.

To find the Sun's declination, enter Table 5th with the signs and degrees of the Sun's true place, anomaly 10s. 2d. and making proportions for the 10m. 12 seconds, take out the Sun's declination, answering to his true place, and it will be found to be 4 degrees, 49 minutes north.

To find the Moon's latitude, this depends on her true distance from her ascending node, which is the same as the Sun's true distance from it at the time of new Moon, and is thereby found in Table 14th. But we have already found, [see Example.] by calculation the Sun's true place, that at the true time of new Moon in April, 1764, the Sun's equated distance from the node was 0s. 7d. 42m. 14s. therefore enter Table 14th with the above equated distance, (making proportions for the minutes and seconds,) her true latitude will be found to be 40 minutes and 18 seconds north ascending.

To find the Moon's horary motion from the Sun, with the Moon's anomaly, namely, 11s. 9d. 24m. 21s. enter Table 15th, and take out the Moon's horary motion, which, by making proportions in that Table, will be found 30 minutes, 22 seconds.

Then with the Sun's anomaly, namely, 9s. 1d. 26m. 19s. (in the present case,) take out his horary motion, 2 minutes and 28 seconds from the same Table; subtract the latter from the former, and the remainder will be the Moon's horary motion from the Sun; namely, 27 minutes and 54 seconds.

To find the angle of the Moon's visible path with the ecliptic. This in the projection of Eclipses, may be always rated at 5 degrees, and 35 minutes without any sensible error.

To find the semi-diameters of the Sun and Moon.

These are found in the same Table, [15] and by the same Argument, as their horary motions. In the present case, the Sun's anomaly gives his semi-diameter, 16 minutes, and 6 seconds, and the Moon's anomaly gives her diameter 14m. and 27 seconds.

To find the semi-diameter of the penumbra. Add the Sun's semi-diameter to the Moon's, and their sum will be the semi-diameter of the penumbra; equal to 31 minutes and 3 seconds.

Collect these elements together, that they may the more readily be found when they are wanted in the construction of this Eclipse. Thus--

	D	H	M	S
1st. The true time of new Moon in April,	1	10	30	25

	D	M	S
2d. Semi-diameter of the Earth's disk,	0	54	53
3d. Sun's distance from the nearest solistic,	77	49	48
4th. Sun's declination north,	4	49	0
5th. Moon's latitude, north ascending,	0	40	18
6th. Moon's horary motion from the Sun,	0	27	54
7th. Angle of Moon's visible path with ecliptic.	5	35	0
8th. Sun's semi-diameter.	0	16	6
9th. Moon's semi-diameter.		14	57
10th. Semi-diameter of the penumbra.		31	3

To project an Eclipse of the Sun Geometrically:—

Make a scale of any convenient length, A. C. and divide it into as many equal parts, as the Earth's semi-disk contains minutes of a degree; which, at the time of the Eclipse in April, 1764, was 54 minutes and 53 seconds; then with the whole length of the scale as a radius, descrtbe the semi-circle **A.** M. B. upon the centre C. which semi-circle will represent the northern half of the Earth's enlightened disk, as seen from the Sun.

Upon the centre C. rises the straight line, Ch. perpendicular to the diameter, A. C. B. then will A. C. B. be a part of the ecliptic, and C. H. its axis.

Being provided with a good sector, open it to the radius C. A. in the line of Chords, and taking from thence the chord of 23 degrees and 28 minutes in your compasses, set it off both ways from H. to g. & g. to h. in the periphery of the semi-disk, and draw the straight line g. V. h. in which the north pole of the disk will be always found.

When the Sun is in Aries, Taurus, Gemini, Cancer, Leo and Virgo, the north pole of the Earth is enlightened by the Sun, but while the Sun is in the other six signs, the south pole is in the dark.

When the Sun is in Capricorn, Aquarius, Pisces, Aries, Taurus and Gemini, the northern half of the Earth's axis, C. XII. P. lies to the right hand of the axis of the ecliptic, as seen from the Sun; and to the left hand, whilst the Sun is in the other 6 signs.

Open * the sector, till the radius, [or distance of the two 90s] of the signs be equal to the length of V. h. and take the sign of the Sun's distance from the solistice 77 degrees, 49 minutes, and 48 seconds in your

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* To persons acquainted with Trigonometry, the angle contained between the Earth's axis, and that of the ecliptic, may be found more accurately by calculation.

RULE.—As Radius is to the sine of the Sun's distance from the solstice, so is the tangent of the distance of the poles, (23 degrees and 28 minutes,) to the tangent of the angle contained by the axis. Then set off the chord of the angle, from H. to h. and join C. H. which will cut F. G. in P. the place of the north pole.

compasses from the line of sines, and set off that distance from V. to P. in the line of g. V. h. because the Earth's axis lies to the right hand of the axis of the ecliptic in this case, [the Sun being in Aries,] and draw the straight line C. XII. P. for the Earth's axis, of which P. is the north pole. If the Earth's axis had lain to the left hand from the axis of the ecliptic, the distance V. P. would have been set off from V. towards g.

To draw the parallel of latitude of any given place, as suppose for LONDON in this case, or the path of that place on the Earth's enlightened disk, as seen from the Sun, from Sun-rise to Sun-set take the following method.

Subtract the latitude of LONDON in this case, 51 degrees and 30 minutes,from 90 degrees, and the remainder 38 degrees and 30 minutes will be the co-latitude, which take in your compasses from the line of chords, making C. A, or C. B. the radius, and set it from h. to the place where the Earth's axis meets the periphery of the disk to VI. and VI. and draw the occult or dotted line VI. K. VI. then from the points where this line meets the Earth's disk set off the chord of the Sun's declination, [4 degrees and 49 minutes,] to A. and F. and to E. and G. and connect these points by the two occult lines. F. XII. G. and A. L. E.

Bisect L. K. XII. in K. and through the point K. draw the black line VI. K. VI. then making C. B. the radius of a line of sines on the sector, take the co-latitude of LONDON, (38 and ½ degrees,) from the sines in your compasses, and set it both ways from K. to VI. and VI. These hours will be just in the edge of the disk at the equinoxes, but at no other time in the whole year. With the extent K. VI. taken into your compasses, set one foot in K. in the black line below the occult one as a centre, and with the other foot describe the semi-circle VI. 7. 8. 9. 10. &c. and divide it into 12 equal parts; then from these points of division, draw the occult 7. p. 8. 0. 9. n. parallel to the Earth's axis, C. XII. P.

With the small extent K. XII. as a radius, describe the quadrantal arc XII. f. and divide it into six equal parts, as XII. a. a. b. bc. cd. de. ef. and through the division points a. b. c. d. e. draw the occult lines VII. e. V. VIII. d. IV. IXC. III. X. b. II. and XI. a. I. all parallel to VI. K. VI. and meeting the former occult lines 7. p. 8. 0. &c. in the points VII. VIII. IX. X. XI. V. IV. III. II. and I. which points will mark the several situations of London on the Earth's disk at these hours respectively, as seen from the Sun, and the elliptic curve VI. VII. VIII. &c. being drawn through these points, will represent the parallel of latitude, or path of London on the disk as seen from the Sun from its rising to its setting.

If the Sun's declination had been south, the diurnal path of London would have been on the upper side of the line VI. K. VI. and would have touched the line D. L. E. in L. It is necessary to divide the hourly spaces into quarters, and if possible into minutes also.

Make C. B. the radius of a line of chords on the sector, and taking therefrom the chord of 5 degrees and 35 minutes, (the angle of the Moon's visible path with the ecliptic ;) set it off from H. to M. on the left hand of C. H. (the axis of the ecliptic,) because the Moon's latitude in this case is north ascending. Then draw C. M. for the axis of the Moon's orbit, and bisect the angle M. C. H. by the right line C. Z. If the Moon's latitude had been north descending, the axis of her orbit would have been on the right hand from the axis of the ecliptic.

The axis of the Moon's orbit lies the same way when her latitude is south ascending, as when it is north ascending, and the same way when south descending, as when north descending.

Take the Moon's latitude (40 minutes and 18 seconds,) from the scale C. A. in your compasses, and set it from i. to x. in the bissecting line C. Z. making i. x. parallel to C. y. and through x. at right angles, to the Moon's orbit, (C. M.) draw the straight line N. w. x. y. s. for the path of the penumbra's centre over the Earth's disk.

The point w. in the axis of the Moon's orbit, is, that, where the penumbra's centre approaches nearest to the centre of the Earth's disk, and consequently is the middle of the general Eclipse. The point x. is where the conjunction of the Sun and Moon falls, according to equal time, as calculated by the Tables, and the point y. is the ecliptical conjunction of the Sun and Moon.

Take the Moon's true horary motion from the Sun, (27 minutes and 54 seconds,) in your compasses, from the scale C. A. (every division of which is a minute of a degree,) and with that extent, make marks along the path of the penumbra's centre, and divide each space from mark to mark, into 60 equal parts, or horary minutes by dots, and set the hours to every 60th minute in such manner, that the dot signifying the instant of new Moon by the Tables, may fall into the point x. half way between the axis of the Moon's orbit, and the axis of the ecliptic; and then the remaining dots will be the points on the Earth's disk, where the penumbra's centre is at the instants denoted by them, in its transit over the Earth.

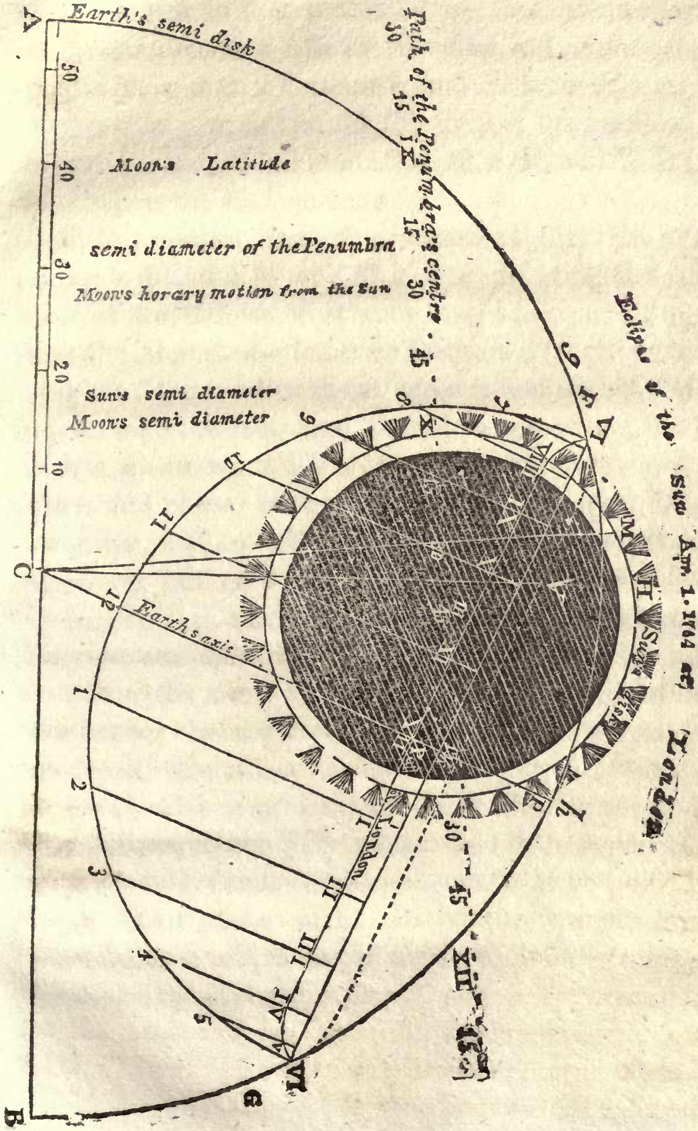
Apply one side of a square to the line of the penumbra's path, and move the square backwards and forwards, until the other side of it cuts the same hour and minute, (as at m. and m.) both in the path of the penumbra's centre, and the particular minute, or instant which the square cuts at the same time in both paths, will be the instant of the visible conjunction of the Sun and Moon, or the greatest obscuration of the Sun at the place for which the construction is made, (namely, London in this Example,) and this instant is at 47 minutes and 29 seconds past 10 o'clock in the morning, which is 17 minutes, 5 seconds later than the tabular time of true conjunction.

Take the Sun's semi-diameter, (16 minutes and six seconds,) in your compasses, from the scale C. A. and setting one foot in the path of London, at m. viz. at

47 minutes and thirty seconds past 10, with the other foot describe the circle U. Y. which will represent the Sun's disk as seen from LONDON at the greatest obscuration.

Then take the Moon's semi-diameter, fourteen minutes and 57 seconds in your compasses from the same scale, and setting one foot in the path of the penumbra's centre at m. in the 47 and ½ minute after 10, with the other foot describe the circle T. Y. for the Moon's disk, as seen from LONDON, at the time when the Eclipse is at the greatest, and the portion of the Sun's disk, which is hidden, or cut off by the disk of the Moon, will show the quantity of the Eclipse at that time, which quantity may be measured on a line equal to the Sun's diameter, and divide it into 12 equal parts for digits, which, in this Example,is nearly eleven digits. This Eclipse was annular at PARIS.

Lastly, take the semi-diameter of the penumbra, 31 minutes and 3 seconds from the scale A. C. in your compasses, and setting one foot in the line of the penumbra's path, on the left hand, from the axis of the ecliptic, direct the other foot towards the path of LONDON, and carry that extent backwards and forwards, until both the points of the compasses fall into the same instants in both the paths, and these instants will denote the time when the Eclipse begins at LONDON. Proceed in the same manner on the right hand of the axis of the ecliptic, and where the points of the compasses fall into the same instants in both the paths, they will show at what time the Eclipse ends at LONDON.


A
Earth's semi disk
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20
10
Moon's Latitude
semi diameter of the Penumbra
Moon's horary motion from the Sun
Sun's semi diameter
Moon's semi diameter
C
Earth's axis
B
Path of the Penumbra's centre
Eclipse of the Sun Apr. 1. 1764 at London
London
Sun's
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According to this construction, this Eclipse began at 20 minutes after 9 in the morning, at LONDON, at the points N. and O. 47 minutes and 30 seconds after 10, at the points m. and m. for the time of the greatest obscuration, and 18 minutes after 12, at R. and S. for the time when the Eclipse ends.

In this construction, it is supposed that the angles under which the Moon's disk is seen during the whole time of the Eclipse, continues invariably the same, and that the Moon's motion is uniform, and rectilinear during that time. But these suppositions do not exactly agree with the truth and therefore supposing the elements given by the Tables to be accurate, yet the times and phases of the Eclipse deduced from its construction, will not answer to exactly what passes in the Heavens, but may be at least two or three minutes wrong, though the work may be done with the greatest care and attention.

The paths also, of all places of considerable latitudes are nearer the centre of the Earth's disk as seen from the Sun, than those constructions make them; because the disk is projected as if the Earth were a perfect sphere, although it is known to be a spheroid.—— The Moon's shadow will consequently go farther northward in all places of northern latitude, and farther southward in all places of southern latitude, than can be shown by any projection.

SECTION SEVENTEENTH.

The Projection of Lunar Eclipses.

When the Moon is within 12 degrees of either of her nodes, at the time when she is full, she will be eclipsed, otherwise not, as before stated,

Required the true time of full Moon, at London, in May, 1762, New Style, and also whether there were an Eclipse of the Moon at that time or not.

It will be found by the Precepts, that at the true time of full Moon in May, 1762, the Sun's mean distance from the ascending node was only 4 degrees, 49 minutes and 36 seconds, and the Moon being then opposite to the Sun, must have been just as near her descending node, and was therefore eclipsed. The elements for the construction of Lunar Eclipses are eight in number, as follows :—

1st, The true time of full Moon.

2d. The Moon's horizontal parallax.

3d. The Sun's semi-diameter.

4th. The Moon's semi-diameter.

5th. The semi-diameter of the Earth's shadow at the Moon.

6th. The Moon's latitude.

7th. The angle of the Moon's visible path with the ecliptic.

8th. The Moon's true horary motion from the Sun.

To find the true time of full Moon, proceed as directed in the Precepts, and the true time of full Moon in May, 1762, will be found on the 8th day, at 50 minutes, and 50 seconds past 3 o'clock in the morning.

To find the Moon's horizontal parallax, enter Table 15th with the Moon's mean anomaly, (at the time of the above full Moon,) namely, 9s. 2d. 42m. 42 seconds, and with it take out her horizontal parallax, which, by making the requisite proportions will be found to be 57 minutes and 23 seconds.

To find the semi-diameters of the Sun and Moon, enter Table 15th, with their respective anomalies, the Sun's being 10s. 7d. 27m. 45 seconds, and the Moon's 9s. 2d. 42m. 42 seconds, (in this case,) and with these take out their respective semi-diameters, the Sun's 15 minutes and 56 seconds, and the Moon's 15 minutes and 38 seconds.

To find the semi-diameter of the Earth's shadow at the Moon, add the Sun's horizontal parallax, (which is always 9 seconds,) to the Moon's which in the present case is 57 minutes and 23 seconds, the Sun will be 57 minutes and 32 seconds; from which subtract the Sun's semi-diameter, 15 minutes and 56 seconds, and there will remain 41 minutes and 36 seconds for the semi-diameter of that part of the Earth's shadow, which the Moon then passes through.

To find the Moon's latitude. Find the Sun's true distance from the Moon's ascending node, (as already taught,) in the first Example for finding the Sun's true place, at the true time of full Moon, and this distance increased by 6 signs, will be the Moon's true distance from the same node, and consequently the Argument for finding her true latitude.

The Sun's mean distance from the ascending node was at the true time of full Moon, 0s. 4d. 49m. 35 seconds; but it appears by the Example that the true time thereof, was 6 hours, 33 minutes and 38 seconds sooner, than the mean time, and therefore we must subtract the Sun's motion from the node during this interval, from the above mean distance 0s. 4d. 49m.and 35 seconds, in order, to have his mean distance from the node, at the time of true full Moon. Then, to this apply the eqnation of his mean distance from the node, found in Table 13th, by his mean anomaly, 10s. 7d. 27m. 45 seconds, and lastly, add six signs, and the Moon's true distance from the ascending node, will be found as follows :—

		S	D	M	S
Sun from node at mean time of full Moon,		0	4	49	35
His motion from the node in	6 hours,			15	35
	33 minutes,			1	26
	38 seconds.				2
Subtract the sum, - - - - - - - - - -				17	3
Remains his mean dist. at true full Moon,		0	4	32	32
Equation of his mean distance, add,			1	38	0
Sun's true distance from the node,		0	6	10	32
To which add, - - - - - - - - - -		6	0	0	0
Moon's true distance from the node,		6	6	10	32

And it is the argument used to find her true latitude at that time. Therefore, with this Argument, enter Table 14th, making proportions between the latitudes belonging to the 6th and 7th degree of the Argument for the 10 minutes, and 32 seconds, and it will give 32 minutes and 21 seconds for the Moon's true latitude, which appears by the Table to be south descending.

To find the angle of the Moon's visible path with the ecliptic. This may be always stated at 5 degrees and 35 minutes without any error of consequence, in the projection of either Solar or Lunar Eclipses.

To find the Moon's true horary motion from the Sun. With their respective anomalies, take out their horary motions from Table 15th, and the Sun's horary motion, subtracted from the Moon's, leaves remaining the Moon's true horary motion from the Sun, in the present case, 30 minutes and 52 seconds.

The above elements are collected for use.

	D	H	M	S
1st. True time of F. Moon in May, 1762	8	3	50	50

	D	M	S
2d. Moon's horizontal parallax,	0	57	23
3d. Sun's semi-diameter,		15	56
4th. Moon's semi-diameter,		15	38
5th. S. diameter of Earth's shadow at Moon,		41	36
6th. Moon's true latitude south descending.		32	21
7th. Angle of Moon's visible path with eclp'tc	5	35	0
8th. Moon's true horary motion from Sun,	0	30	52

These elements being found for the construction of the Moon's Eclipse in May, 1762, proceed as follows :—

Make a scale of any convenient length, as W. X. and divide it into 60 equal parts, each part standing for a minute of a degree. Draw the right line A. C. B. for part of the ecliptic, and C A perpendicular thereto for the southern part of its axis, (the Moon having south latitude,)

Add the semi-diameters of the Moon and Earth's shadow together, which in this case, make 57 minutes and 14 seconds; and take this from the scale in your compasses, and setting one foot in the point C. as a centre, with the other describe the semi-circle S. D. B. in one point of which the Moon's centre will be at the beginning of the Eclipse, and the other at the end.

Take the semi-diameter of the Earth's shadow, (41 minutes and 36 seconds,) in your compasses from the scale, and setting one foot in the centre C. with the other describe the semi-circle K. L. M. for the southern half of the Earth's shadow, because the Moon's latitude is south in this Eclipse.

Make C. D. equal to the radius of a line of chords on the sector, and set off the angle of the Moon's visible path with the ecliptic, (5 degrees and 35 minutes,) from D. to E. and draw the right line C. F. E. for the southern half of the axis of the Moon's orbit, lying to the right hand from the axis of the ecliptic C. A. because the Moon's latitude is south descending in this Eclipse. It would have been the same way on the other side of the ecliptic, if her latitude had been north descending, but contrary in both cases, if her latitude had been either north, or south ascending.

Bisect the angle A. C. E. by the right line C. g. in in which the true equal time of opposition of the Sun aud Moon falls, as found from the Tables.

Take the Moon's latitude, 32 minutes and 21 seconds, from the scale in your compasses, and set it from C. to G. in the line C. G. g. and through the point G. at right angles to C. F. E. draw the right line P. H. G. F. N. for the path of the Moon's centre. Then F. shall be the point in the Earth's shadow, where the Moon's centre is, at the middle of the Eclipse ; G. the point where her centre is at the tabular time of her being full ; and H. the point where her centre is,at the instant of her ecliptical opposition.

Take the Moon's horary motion from the Sun, (30 minutes and 52 seconds,) in your compasses from the scale W. X. and with that extent, make marks along the line of the Moon's path, P. G. N. then divide each space from mark to mark, into 60 equal parts, or horary minutes, and set the hours to the proper dots in such manner, that the dots signifying the instant of full Moon, namely,(50 minutes and 50 seconds after 3 in the morning,) may be in the point G. where the line of the Moon's path enters the line that directs the angle D. C. E.

Take the Moon's semi-diameter, 15 minutes and 38 seconds in your compasses from the scale, and with that extent, as a radius upon the points N. F. and P. as centres, describe the circle Q. for the Moon at the beginning of the Eclipse, when she touches the Earth's shadow at V.; the circle R. for the Moon at the middle, and the circle S. for the Moon at the end of the Eclipse, just leaving the Earth's shadow at W.

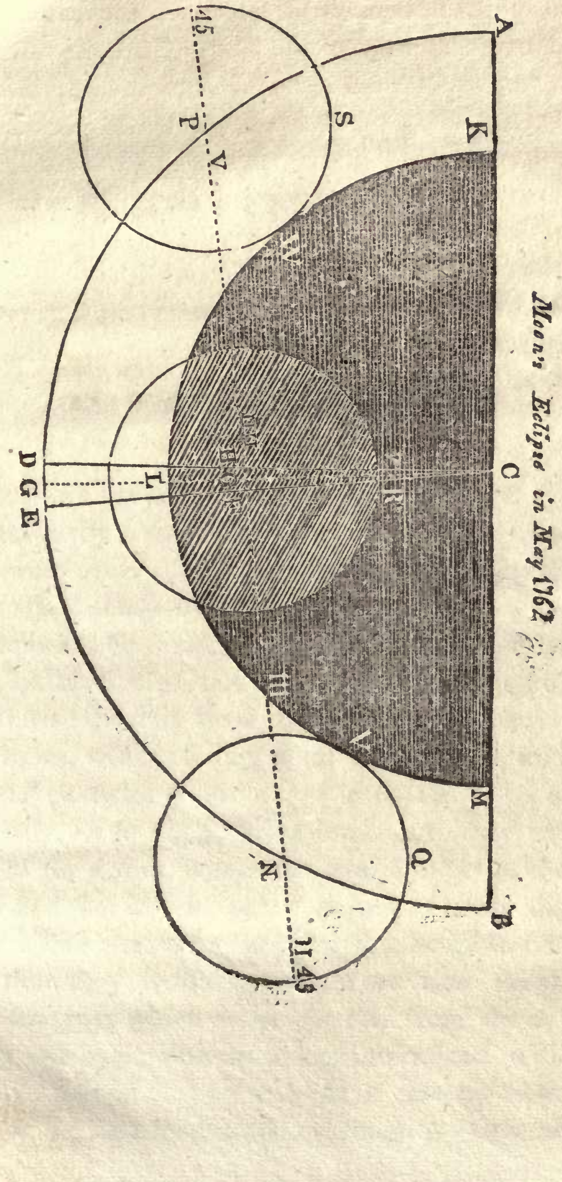
The point N. denotes the instant when the Eclipse begins, namely, at 15 minutes and 10 seconds after two in the morning. The point F. the middle of the Eclipse, at 47 minutes and 45 seconds after three, and the polnt P. the end of the Eclipse, at eighteen minutes after five, at the greatest obscuration, the Moon was ten digits eclipsed.

The Moon's diameter, (as well as the Sun's,) is supposed to be divided into 12 equal parts, (called digits,) and so many of these parts as are darkened by the Earth's shadow, so many digits is the Moon eclipsed. All that the Moon is eclipsed above 12 digits, show how far the shadow of the Earth is over the body of the Moon, on that edge, to which she is nearest, at the middle of the Eclipse, It is difficult to observe exactly, either the beginning or ending of a Lunar Eclipse, even with a good Telescope; because the Earth's shadow is so faint, and ill-defined about the edges, that when the Moon is either just touching or leaving it, the obscuration of her limb is scarcely sensible, and therefore the closest observers can hardly be certain to four or five seconds of time.

But both the beginning and ending of Solar Eclipses, are instantaneously visible, for the moment that the edge of the Moon's disk touches the Sun's, his roundness appears to be broken on that part, and the moment she leaves it, he appears perfectly round again.

In Astronomy, Eclipses of the Moon are of great use in ascertaining the periods of her motions, especially such Eclipses as are observed to be alike in all circumstances, and have long intervals of time between them. In Geography, the longitude of places are found by Eclipses. The Eclipses of the Moon are more useful for this purpose, than those of the Sun; because they are more frequeutly visible, and the same Lunar Eclipse is equally large, at all places where it is seen.

In Chronology, both Solar and Lunar Eclipses serve to determine exactly the time of any past event; for there are so many particulars observable in every Eclipse with respect to its quantity—the places where it is perceivable, (if of the Sun,) and the time of the day, or night, that it is impossible that there can be two Solar Eclipses in the course of many ages, which are alike in all circumstances. From the preceding explanation of the doctrine of Eclipses, it is evident that the darkness at the CRUCIFIXION of our SAVIOUR was not occasioned by an Eclipse of the Sun. For he suffered on the day on which the PASSOVER was eaten by the JEWS, namely, the third day of April, A. D. 33: on that day, it was impossible that the Moon's shadow could fall on the Earth's. For the JEWS kept the PASSOVER at the time of full Moon; nor does the darkness in total Eclipses of the Sun, last above four minutes and six seconds in any place; whereas the darkness at the CRUCIFIXION lasted three hours, and overspread, at least, all the Land of JUDEA.



Moon's Eclipse in May 1762

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SECTION EIGHTEENTH.

ON THE FIXED STARS.

The Stars are said to be fixed, because they have been generally observed to keep at the same distances from each other; their apparent diurnal revolutions being caused solely by the Earth's turning on its axis. They appear of a sensible magnitude to the eye, because the retina is affected, not only by the rays of light which are remitted directly from them, but by many thousands more, which, falling upon our eye-lids, and upon the aerial particles about us, are reflected into our eyes so strongly, as to excite vibrations, not only in those points of the retina, where the real images of the stars are formed, but also in other points of some distance round. This makes us imagine the Stars to be much larger than they would appear, if we saw them only by the few rays which come directly from them, so as to enter our eyes, without being intermixed with others. Any person may be sensible of this, by looking at a Star of the first magnitude, through a long, narrow tube, which, though it takes in as much of the sky as would hold a thousand such stars, yet scarcely renders that one visible.

The more a telescope magnifies, the less is the aperture through which the star is seen; and consequently the less number of rays it admits into the eye. The stars appear less in a telescope which magnifies 200 times, than they do to the naked eye; insomuch that they seem to be only indivisible points; it proves at once that the stars are at immense distances from us, and that they shine by their own proper light. If they shone by reflection, they would be as invisible without telescopes, as the satellites of Jupiter. These satellites appear larger when viewed with a good telescope, than any of the fixed stars.

The number of stars discoverable in either hemisphere by the unaided sight, is not above a thousand. This at first, may appear increditable: because they seem to be almost innumerable, but the deception arises from our looking confusedly upon them without reducing them to any order: look steadfastly upon a large portion of the sky, and count the number of stars in it, and you will be surprised to find them so few. Consider only how seldom the Moon's passes between us and any star, (although there are as many about her path, as in any other parts of the Heavens;) and you will soon be convinced that the stars are much thinner sown, than you expected. The British catalogue, which, besides the stars visible to the naked eye, includes a great number which cannot be seen, without the assistance of a telescope, contains no more than three thousand in both hemispheres.

As we have incomparably more light from the Moon, than from all the stars together, it is the greatest absurdity to imagine, that the stars were made for no other purpose than to cast a faint light upon the earth ; especially, since many more require the assistance of a good telescope to find them out, than are visible without that instrument. Our Sun is surrounded by a system of planets, and comets, all of which would be invisible from the nearest fixed star : And, from what we already know of the immense distance of the stars, the nearest may be computed at 32 billions of miles from us, which is farther than a cannon ball can fly in 7 millions of years, though it proceeded with the same velocity as at its first discharge. Hence it is easy to prove, that the Sun, seen from such a distance would appear no larger than a star of the first magnitude. From the foregoing observations it is highly probable, that each star is the centre of a magnificent system of worlds, moving round it, though unseen by us, and are irradiated by its beams : especially, as the doctrine of plurality of worlds is rational, and greatly manifests the power, wisdom and goodness of the great Creator.

The stars, on account of their apparently various magnitudes have been distributed into several classes, or orders. Those which appear largest are called stars of the first magnitude, the next to them in lustre, stars of the second magnitude, and so on to the sixth, which are the smallest that are visible to the unaided sight.—

This distribution, having been made long before the invention of telescopes, the stars which cannot be seen without the assistance of these instruments, are distinguished by the name of telescopic stars.

The ancients divided the starry spheres into particular constellations, or systems of stars, according as they lay near each other, so as to occupy those spaces which the figures of different sorts of animals, or things would take up, if they were there delineated. And those stars which could not be brought into any particular constellation, were called unformed stars.

This division into different constellations or asterisms. serves to distinguish them from each other; so that any particular star may be readily found in the Heavens, by means of a celestial globe, on which the constellations are so delineated, as to put the most remarkable stars into such parts of the figures, as are most easily distinguished. The number of ancient constellations is 48, and upon our present globes, about 70. There is also a division of the Heavens into three parts. First the Zodiac, signifying an animal, because most of the constellations in it, which are twelve in number, are the figures of animals, as Aries, the ram, Taurus, the bull, Gemini, the twins, Cancer, the crab, Leo, the lion. Virgo, the virgin, Libra, the balance, Scorpio, the scorpion, Sagitarius, the archer, Capricornus, the goat, Aquarius, the water-bearer, and Pisces, the fishes.-—The Zodiac goes quite round the Heavens, it is about 16 degrees broad, so that it takes in the orbits of the Moon, and of all the planets, (excepting that of Pallas, and the satellites of Herschel.) Along the middle of this zone, or belt, is the ecliptic, or circle which the earth describes annually, as seen from the Sun, and which the Sun appears to describe as seen from the earth. Second. All that region of the Heavens which is on the north side of the Zodiac, containing 21 constellations: And, Third, that region on the south side of the Zodiac, containing 15 constellations.

There is a remarkable track around the Heavens, called the Galaxy, or Milky Way from its peculiar whiteness. It was formerly thought to be owing to a vast number of very small stars, closely connected,and the observation of Dr. Herschel have fully confirmed the opinion. He therefore considers the Galaxy as a very extensive branching congeries of many millions of stars, which probably owes its origin to several remarkable large, as well as very closely scattered small stars, that may have drawn together the rest.

ON GROUPS OF STARS.

Groups of Stars, succeed to clustering Stars in Dr. Herschel's arrangement. A group is a collection of Stars, closely, and almost equally compressed, and of any figure or outline. There is no particular condensation of the Stars to indicate the existence of a central force, and the groups are sufficiently separated from neighboring stars, to show that they form peculiar systems of theirown.

ON CLUSTERS OF STARS.

Dr. Herschel regards Clusters of Stars as the most magnificent objects in the Heavens. They differ from groups in their beautiful and artificial arrangement.—Their form is generally round, and their condensation is such as to produce a mottled lustre, somewhat resembling a nucleus. The whole appearance of a cluster indicates the existence of a central force, residing either in a central body, or in the centre of gravity of the whole system.

Interrogations for Section Eighteenth.

What is a fixed Star?

Why do they appear of sensible magnitude to the eye?

Do the Stars appear larger when viewed through a telescope, than viewed with the eye only?

What does it prove?

Which appear the largest, the satellites of Jupiter, or the Stars, when viewed with a telescope?

About how many Stars in a clear night can be seen by the naked eye?

How many in the British catalogue?

Are some of that number telescopic?

Would the planets and comets of the Solar System be invisible from the nearest Star?

At how many miles distant may we with propriety, suppose the nearest fixed Star?

How long would a cannon ball be in flying that distance, supposing it should continue to move with the same velocity, as at its first discharge ?

Of what size would the Sun probably appear from the nearest fixed Star ?

Is it not probable that every Star is the centre of a magnificent system ?

On what account have they been distributed into classes ?

What are those called which appear largest ?

What are Constellations ?

What is the use of dividing them into Constellations ?

How many Constellations on the celestial globes ?

What is the Zodiac ?

How many Constellations in the Zodiac ?

What is the breadth of the Zodiac ?

What the Galaxy, or Milky Way ?

What is a Group of Stars ?

What are Clusters of Stars ?

SECTION NINETEENTH.

AN ACCOUNT OF THE GREGORIAN, OR NEW STYLE, TOGETHER WITH SOME CHRONOLOGICAL PROBLEMS, FOR FINDING THE EPACT, GOLDEN NUMBER, DOMINICAL LETTER, &C.

Pope Gregory Thirteenth, made a reformation of the calendar. The Julian calender, (or Old Style,) had before that time, been in general use all over Europe. The year, according to the Julian calendar, consists of 365 days and 6 hours, which 6 hours being ¼ part of a day, the common years consisted of 365 days: and every fourth year, one day was added to the month of February, which made each of those years consist of 366 days, commonly called leap years.

This computation, (though near the truth,) is more than the Solar year, by 11 minutes and 3 seconds, which, in 131 years amounts to a whole day. By which the Vernal Equinox was anticipated ten days from the time of the general council of Nice, held in the year 325 of the Christian Era, to the time of Pope Gregory, who therefore caused ten days to be taken out of the month of October, 1582, to make the Equinox full on the 21st of March, as it did at the time of that council; and to prevent the like variation for the future, he ordered that three days should be abated in every four hundred years, by reducing the leap year at the close of each century, for three successive centuries, to common years, and retaining the leap year at the close of each fourth century only. This, at that time, was esteemed as exactly conformable to the true solar year. But since that time, the true solar year is found to consist of 365 days, 5 hours, 48 minutes and 49 seconds, which in 50 centuries will make another day's variation.

Though the Gregorian Calendar, (or New Style,) had long been in use throughout the greatest part of Europe, it did not take place in Great Britain and America, till the first of January, 1752, and in September following, the 11 days were adjusted by calling the third day of that month, the fourteenth, and continuing the rest in their order.

CHRONOLOGICAL PROBLEMS.

As there are three leap years to be abated in every four centuries, to find which century is to be leap year and which not.

Rule.—Cut off two cyphers from the given year, and divide the remaining figures by 4, if nothing remain, the year will be leap year.

The year $4)\frac{19(00}{4-3}$ there being a remainder of 3, it will not be leap year. But the year $4)\frac{20(00}{5}$ will.

To find the Dominical or Sunday Letter.

Rule.—To the given year, add its fourth part, rejecting remainders, divide the sum by 7, and if there be no remainder, A is the Sunday letter; but if any number remains, then the letter standing under that number, is the Dominical letter, and the day of the week on which the year commences.

A leap year has two Dominical letters, the first of which commences the year, and continues to the 24th of February, and the other to the end of the year.

EXAMPLE.

1	2	3	4	5	5	7
Sunday,	Monday,	Tuesday,	Wednesday,	Thursday,	Friday,	Saturday,
0	1	2	3	4	5	6
A	**G**	**F**	**E**	**D**	**C**	**B**

Required the Dominical letters for the years 1832.

4)1832
458
Days in a week 7)2290
327—1

The year 1832, was leap year, & according to the work, the remainder being 1, the first Sunday letter was A, and G was the second, the year also commenced on Sunday.

To find the Golden Number.

Rule.—Add 1 to the given year, divide the sum by 19, and the remainder will be the Golden Number: if nothing remain, then 19 will be the number sought.

Required the Golden Number for the year 1832,

To the given year 1832
Add 1
19)1833(96
171
123
114
Golden Number, 9

To find the Epact.

Rule.—Subtract 1 from the Golden Number, divide the remainder by 3, if 1 remain, add 10 to the dividend, the sum will be the Epact; if nothing remain, the dividend is the Epact.

Required the Epact for the year 1832. The Golden Number, as found above, is 9, therefore, subtract 1, and the remainder is 8, divide 8 by 3, and the quotient is two, and 2 remains, multiply this remainder by 10, and the product is 20, to which add the dividend, and the sum is 29, the Epact for 1832.

To find the year of the Dionysian Period.

Rule.—Add to the given year 457, divide the sum by 532, and the remainder will be the number required.

Required the year of the Dionysian Period, for the year 1832. To the given year, 1832.

Add 457
532)2289(4
2128
161=Dionysian Period.

To find the Julian Period.

Rule.—Add 4713 to the given year, and the sum will be the Julian Period.

Required the Julian Period for the year of the Christian Era, 1832. 1832
4713
6545 year of the julian period.

*To find the Cycle of the Sun, Golden Number, and Indiction for any Current Year.

Rule.—To the current year add 4713, divide the sum by 28, 19, and 15, respectively, and the several remainders will be the numbers required. If nothing remains, the divisors are the required numbers.

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* A Cycle is a perpetual round, or circulation of the same parts of time of any sort. The Cycle of the Sun, is a revolution of 28 years, in which the days of the months return again to the same days of the

Required the Cycle of the Sun, Golden Number, & Indiction for the year 1832.

1832	1832	1832
4713	4713	4713
28)6545(233	19)6545(344	15)6545(436
56	57	60
94	84	54
84	76	45
105	85	95
84	76	90

21=Cycle of the Sun 9=Golden Number 5=Indiction.

To find on what day Easter will happen.

It was ordered by the Nicene Council, that Easter Sunday, should be kept on the first Sunday after the 1st full Moon which happened upon,or after the twenty-first day of March, the day on which they thought the Vernal Equinox happened, though this was a mistake, for the vernal equinox that year fell on the 20th of March; but yet, the full Moon which fell on, or next after the twenty-first of March, they called the Paschal full Moon; and by the introduction of the Gregorian, or New Style, the equinox will now always happen on the twentieth, or twenty-first of March : and if the full Moon happen on a Sunday, Easter Day is to be the next Sunday after. Therefore, find the time of the next full Moon after the 21st. of March, and the following Sunday is Easter.

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of the week, the Sun's place to the same signs and degrees of the ecliptic, on the same months and days, so as not to differ one degree in an hundred years, and the leap years begin the same course over again, with respect to the days of the week, on which the days of the months fall.

The Cycle of the Moon, (commonly called the Golden Number,) is a revolution of 19 years, in which the conjunctions, oppositions, and other aspects of the Moon, are within an hour and a half, of being the same as they were, on the same days of the months 19 years before. The indiction is a revolution of 15 years, used only by the ROMANS, for indicating the times of certain payments made by the subjects of the REPUBLIC : It was established by CONSTANTINE, A. D. 312.

PERPETUAL ALMANAC.

February. March. November.	*February August.	May.	January. October.	*January. April. July.	September. December.	June.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

To find on what day of the week, any given day in any month will fall, and the Contrary.

EXAMPLE.

On what day of the week will the first day of January fall in 1840.

Observe the day of the week annexed to the year in the outer column, then in the table under the given month, in the upper row of figures yon will find the day of the month on which that day falls. According to this direction, I find that in the year 1840 (being leap year) that the 5th day of January is on Sunday, and consequently the year 1840 commences on Wednesday.

NOTE—In leap years, January and February must be taken in the columns marked thus *. Leap years are marked in the outer columns thus †,

The years 2000, 2400,2800 and every 400th year following are leap years.

1800	Saturday,	
1801	Sunday,	
1802	Monday,	
1803	Tuesday,	
1804	Thursday,	†
1805	Friday,	
1806	Saturday,	
1807	Sunday,	
1808	Tuesday,	†
1809	Wednesday	
1801	Thursday,	
1811	Friday,	
1812	Sunday,	†
1813	Monday,	
1814	Tuesday,	
1815	Wednesday,	
1816	Friday,	†
1817	Saturday,	
1818	Sunday,	
1819	Monday,	
1820	Wednesday,	†
1821	Thursday,	
1822	Friday,	
1823	Saturday,	
1824	Monday,	†
1825	Tuesday,	
1826	Wednesday,	
1827	Thursday,	
1828	Saturday,	†

1829	Sunday,	
1830	Monday,	
1831	Tuesday,	
1832	Thursday,	†
1833	Friday,	
1834	Saturday,	
1835	Sunday,	
1836	Tuesday,	†
1837	Wednesday,	
1838	Thursday,	
1839	Friday,	
1840	Sunday	†
1841	Monday,	
1842	Tuesday,	
1843	Wednesday,	
1844	Friday,	†
1845	Saturday,	
1846	Sunday,	
1847	Monday,	
1848	Wednesday,	†
1849	Thursday,	
1850	Friday,	
1851	Saturday,	
1852	Monday	†
1853	Tuesday,	
1854	Wednesday,	
1855	Thursday,	
1856	Saturday,	

TABULAR VIEW OF THE SOLAR SYSTEM.

Names of the Planets.	Mean diameters in Miles.	Mean distances from the Sun in round numbers of Miles.	The correct mean distances, that of the earth being 100000	Mean apparent diameters as seen from the earth.			Mean apparent diameter as seen from the Sun.
				M	S	3DS.	
The Sun	883,246			32	1	30	
Mercury	3,224	37,000,000	38,710		10		16 seconds.
Venus	7,687	68,000,000	72,333	0	58	0	30
Earth	7,912	95,000,000	100,000				17,2
Moon	2,180	95,000,000	100,000	31	8		4,6
Mars	4,189	144,000,000	152,369	0	27	0	10
Vesta	238	225,000,000	237,300	0	0	30	
Juno	1,425	252,000,000	265,700	0	3	0	
Ceres	163 1,024	263,000,000	276,500		1 6,4		
Pallas	80 20,99	265,000,000	279,100		,5 6,5		
Jupiter	89,170	490,000,000	520,279	0	39	0	37
Saturn	79,042	900,000,000	954,072		18		16
Herschel	35,112	1,800,000,000	1,908,352	3	54		4

TABULAR VIEW OF THE SOLAR SYSTEM.

NAMES OF THE Planets.	Tropical Revolutions.				Sydereal Revolutions.				Place of Aphelion in Jan. 1800			
Sun	S	D	M	S	D	H	M	S	D	H	M	S
Mercury	87	23	14	32	87	23	15	34	8	14	20	50
Venus	224	16	41	27	224	16	49	10	10	7	59	1
Earth	365	5	48	49	365	6	9	12	9	8	40	12
Moon												
Mars	686	22	18	27	686	23	30	35	5	2	24	4
Vesta	1155	4							2	9	42	53
Juno	1588								7	29	49	33
Ceres	1681								4	25	57	15
Pallas					1703	16	48		10	1	7	0
Jupiter	4330	14	39	2	4332	14	27	10	6	11	8	20
Saturn	10746	19	16	15	10759	1	51	11	8	29	4	11
Herschel	30637	4	0	0	30737	18	0	0	11	16	30	31

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